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Development of a field-Deployable assay to Detect *Verticillium dahliae* in Peppermint Crops

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The ability to detect pathogens using DNA-based molecular approaches makes it possible to detect *V. dahliae* before wilt development and can enable more informed management practices based on disease risk. A quantitative PCR test has been used routinely by our team for the detection of *V. dahliae* from soils. However, this method relies on relatively expensive and specialized equipment, which limits its utility in the field. A quick, field deployable assay for *Verticillium* could be used by growers and stakeholders to rapidly determine if the pathogen is present in a field or a plant. Such a test could also be useful when selecting fields to plant or when producing certified, disease-free rootstock.

Recombinase polymerase amplification (RPA) technology is an alternative to traditional PCR-based methods but can be performed in the absence of an electricity supply, which increases its utility in field conditions. In addition, RPA technology has high sensitivity, requires minimal sample preparation and can have rapid amplification at a relatively low reaction temperature (around 104°F). More importantly, RPA assays can be combined with a lateral flow dipstick (LFD) to perform visual detection of pathogens in the field.

MIRC-funded research in 2022-2023 was successful at designing five RPA primers and probe combinations that targeted the beta-tubulin gene of *V. dahliae*. Primers were screened against 20 *Verticillium* isolates in the lab and exhibited specificity to *V. dahliae*, including 13 VCG 2B isolates from *Mentha*. We were also successful at visualizing DNA amplification using a LFD (Fig. 1). In silico analyses showed that the primers and probes exhibited specificity for *V. dahliae*, with the exception of the potential for cross-reaction with some *V.* x *longisporum* isolates, which is a hybrid of *V. dahliae* and another *Verticillium* species and consequently share portions of their genomes. In practice this is not expected to be an issue since *V.* x *longisporum* is a pathogen specific to canola and not associated with mint.

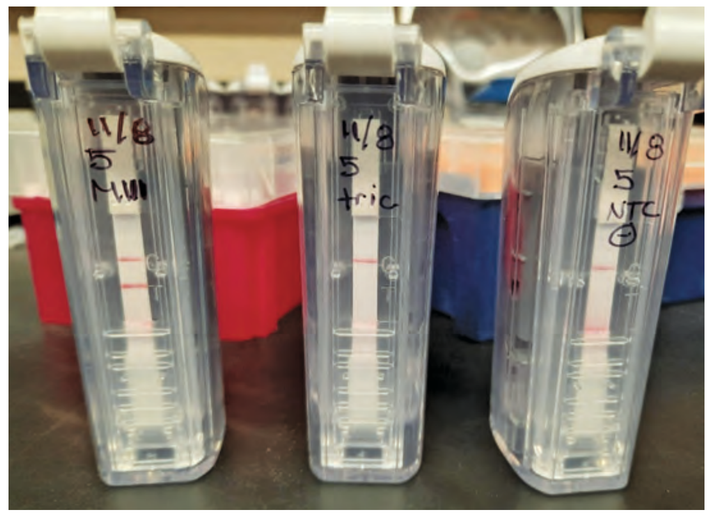

Fig. 1. Visualization of recombinase polymerase amplification products using a lateral flow device. The bottom band indicates successful amplification, while the top band is a control band. Left to right: *V. dahliae* isolate M-111 from peppermint, *V. tricorpus*, negative control.

Table 1. Sensitivity of the recombinase polymerase amplification (RPA) assay using *Verticillium dahliae* DNA extracts obtained from pure culture (detections/attempts).

DNA	RPA detection
1 fg	0/2
10 fg	1/4
100 fg	4/4
100 pg	1/1
1 ng	20/20

The RPA-LFD assay was able to detect 10 fg of *V. dahliae* DNA extracted from pure cultures of the pathogen (Table 1). However, 100 percent detection was only observed using 100 fg. For reference, the approximate mass of one *V. dahliae* genome is 29.6 fg and published qPCR assays are reported to be able to detect as little as 3 to 10 fg of *V. dahliae* DNA, depending on the target gene and type of assay.

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Table 2. Detection of *Verticillium dahliae* in naturally-infested soils using the Andersen air sampler (reported as CFU/g soil), quantitative PCR (reported as fg DNA) and the recombinase polymerase amplification (RPA) assay

Andersen air sampler (CFU/g soil)	Quantitative PCR (fg DNA)	RPA assay
0	0.0	-
0	8.5	-
0	24.6	-
0	107.1	-
0	244.9	+
6	516.1	+
53	1156.2	+
135	3524.0	+

The RPA-LFD assay was able to detect the pathogen in four out of eight lab-based DNA extracts obtained from naturally-infested soil samples, which was more than plating (three out of eight) but less than the qPCR assay (seven out of eight) (Table 2). However, of the different field-deployable buffers and protocols tested for potential use with soil samples, only the boiled (100°C for 30 min) dry nonfat milk treatment resulted in DNA that was detectable using qPCR (data not shown), suggesting that more research is needed if this assay is to be applied to soil samples in the field.

The RPA-LFD assay was able to detect the *V. dahliae* pathogen from boiled (100°C for 8 min) stem sap obtained from symptomatic plant stems and/or leaves. These results indicate that a crude DNA extraction step is not required when testing plant material using the RPA-LFD assay, which would facilitate the use of this test under field conditions. Additionally, the RPA-LFD assay was also able to detect the pathogen in asymptomatic plants 7 and 14 days after inoculation (Table 3) and can be completed in less than 60 min.

Table 3. Detection of *Verticillium dahliae* in artificially-inoculated peppermint plants using the recombinase polymerase amplification (RPA) assay (detections/attempts)

Days post-inoculation	Mean disease rating*	RPA detection
2	0.0	0/5
7	0.0	3/5
14	0.0	2/5
22	1.0	4/5
30	2.0	3/5
42	2.4	5/5
69	3.8	4/4

*Disease ratings ranged from 0 = no visible symptoms to 5 = dead or nearly dead plant.

Identifying Weeds in Mint with Aerial Imagery for the Purpose of Spot Spraying – Oregon State University Weed Science Mint Research

Dr. Pete Berry, Oregon State University

Integrating geographic information systems (GIS) into farm equipment has enabled precision agriculture practices. The recent advancement and production of spot sprayers demonstrates the benefits of GIS application technology where sensors can identify weeds. However, the ability to spot spray weeds during active crop growth is commercially limited to large acreage row crops like corn, soybean and cotton. However, the need and benefit of this technology are potentially more impactful in specialty crops due to the limitation of new active ingredients or challenges in labeling of existing herbicides. Using aerial imagery to map weed populations in mint could enable the use of specialty spot sprayers. These systems could potentially target different weed species depending on the impact on oil yields or oil quality. These systems also allow non-selective herbicide applications during non-dormant times. The use of specialty spot sprayers is a unique way to target weeds and has not been done in mint previously.

The benefit of the described research will allow GIS technology to be adapted for the use in mint production as well as other specialty crops with the goal of decreasing the cost of production and increasing weed management. The outcome of this research will demonstrate how GIS technology can be utilized for weed management in mint production with existing technology and application equipment.

Two separate mint fields had areas imaged with a multispectral sensor at 65, 82, 98 and 115 feet altitudes to determine the required resolution for weed identification. In addition to a multispectral sensor, a high resolution (.15 inch) red-green-blue (RGB) sensor was flown on one of the fields to further evaluate resolution requirements to identify weeds in mint. Multiple weeds were identified visually and points obtained using a hand-held RTK system to GPS weeds identified in the images. Image classification is ongoing but individual species have been classified within the imagery (Figure 1). The classified weed populations can then be isolated with the associated GPS location in the field.

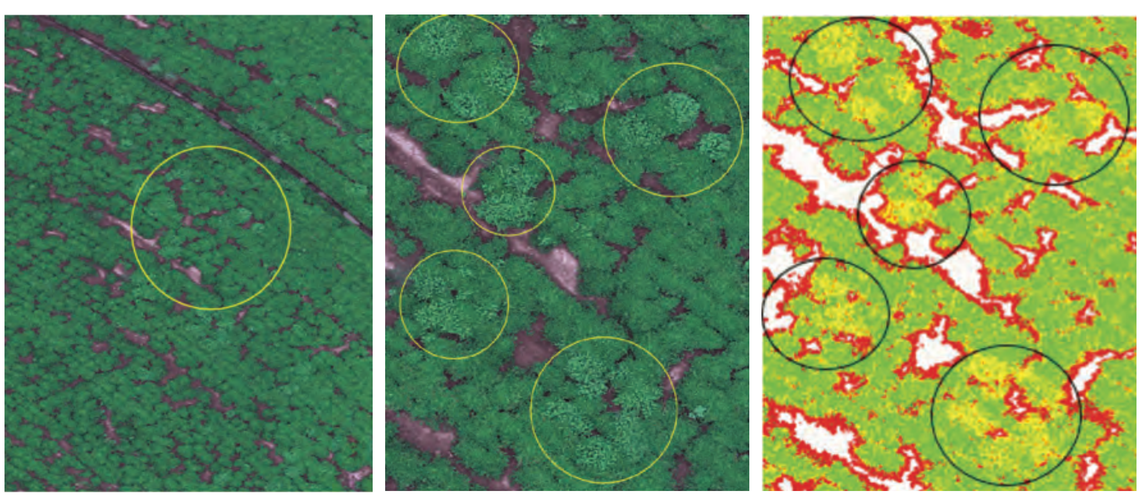
The OSU weed science program integrated spatial data into their tractor's operation center and spot sprayer. This data encompassed 31 distinct areas, varying in size from 1 to 10 square feet. As the sprayer was driven over these areas, individual nozzles were activated in accordance with the size of each zone, allowing precise applications. Each of the 31 areas (representing potential weed populations) received targeted spraying, showcasing the efficacy of the spot sprayer.

The success of the trial demonstrated the feasibility of uploading drone aerial imagery into the sprayer system and utilizing GPS coordinates derived from the imagery for precise spraying. However, integrating multiple GIS technologies, including drones, GPS systems and RTK-enabled tractors presents challenges. Each system operates with its own accuracy but relies on different data sources for location information. Consequently, merging these systems into a unified, precise location can introduce errors.

To address this challenge, we are processing GPS points and images, layering them and conducting further analysis to identify and rectify any discrepancies. Ongoing testing involves evaluating the performance of the John Deere 6000 and 7000 globe RTK systems. Notably, the 7000 series globe shares the same RTK system as the drone (solely reliant of satellite GPS coordinates), facilitating the integration and enhancing accuracy.

Moving forward, research efforts will continue to focus on two primary objectives. Firstly, identifying weeds in mint fields using advanced imaging technologies. Secondly, the integration of imagery into the spot sprayer system to leverage GIS technologies for more effective weed control. Oregon State University's weed science program is committed to advancing the integration of GIS technologies to enhance weed management practices for Oregon's growers.

Figure 1: Black nightshade identified in a mint field and classified using supervised model training.



Fungicide Evaluation for Control of Rusts and Crop Safety in Mint

Kyle Roerig, Research Agronomist, Pratum Co-op

Introduction

Rust, *Puccinia menthae*, is a significant fungal pathogen which reduces yield in mint, especially mint grown in western Oregon. Currently registered fungicides fall short of controlling the disease at registered rates. Additionally, reliance on a limited group of fungicide modes of action increases the risk of the pathogen developing resistance to the fungicide. Increasing fungicide options may improve rust control, preserving crop yield and reducng the risk of fungicide resistance.

Research Objective

This study was designed to evaluate fungicides for efficacy against rust and crop safety in mint. The seven fungicides in this study were identified as having efficacy in a 2021 trial. They were evaluated in 2022. Manufacturers require efficacy and crop safety data from multiple years and locations before supporting the registration of a new crop use. This data is intended to be used as a step towards registration of one or more of the fungicides included in the study.

Methods

Seven fungicides that were identified in 2021 as effective in controlling rust in mint were evaluated for rust control and crop safety in mint. Each fungicide was applied as a single application and as sequential applications based on the highest number of repeat applications allowed in other crops on the product label. These were compared to azoxystrobin-propiconazole (Quilt Excel, Syngenta) as single and repeat applications and an untreated check. The fungicides evaluated in this trial were fluxapyroxad-pyraclostrobin (Priaxor, BASF), azoxystrobin-benzovindiflupyr-propiconazole (Trivapro, Syngenta), azoxystrobin-benzovindiflupyr (Elatus, Syngenta), inpyrfluxam (Excalia, Valent), mefentrifluconazole-pyraclostrobin-fluxapyroxad (Revytek, BASF), picoxystrobin-cyproconazole (Aproach Prima,

Table 1. Site and application information.

Site Description	
Crop	Peppermint
Variety	M83-7
Stand age	Third year
Soil	Sifton gravely loam
Location	44.809209, -122.864343

Application	A	B	C
Date	6/3/2023	6/28/2023	8/1/2023
Start Time	8:20 AM	10:00 AM	8:00 AM
Stop Time	10:00 AM	2:00 PM	9:15 AM
Air Temperature	63 F	80 F	67 F
Relative humidity	55%	46%	67%
Wind	5 MPH, N	3 MPH, NNW	6 MPH, N
Max wind	7 MPH	5 MPH	9 MPH
Wet Leaves (Y/N)	Yes	No	Yes
Soil Temperature	65 F	66 F	
Soil Moisture	Moist	Moist	Moist
% Cloud Cover	0	0	0
Crop stage	4-12″	6-18″	Early bloom
Pest stage	Pre infection	Pre infection	Pre infection

Corteva) and penthiopyrad (Fontelis, Corteva). The trial was conducted as a randomized complete block design with four replications in an established mint field in Marion County, Oregon. Fungicide applications were made June 3, 2023; June 28, 2023; and August 1, 2023 (Table 1). Single applications were made June 8, 2022. The treatments (Table 2) were applied using a wheeled plot sprayer or CO_2 backpack sprayer at 20 gallons of carrier per acre using Greenleaf AM11003 nozzles. Rust control and peppermint injury evaluations were made June 28, July 26, August 18, 2023. The mint plots were swathed August 19, 2023; chopped August 23, 2023; and distilled August 24-25, 2023.

Results

At the June and July evaluations no rust was visible, nor was any injury observed at any three of the evaluations (data not shown). By July 18, just prior to swathing, rust was observed in the plots. All of the multiple application fungicide treatments, except Aproach Prima, had significantly lower rust pressure than the untreated (at p-value 0.05, Table 3). With single applications of Trivapro, Elatus, Excalia, Revytek and Fontelis plots had significantly lower rust pressure. Peppermint oil yields did not significantly differ from the untreated in any of the treatments.

Table 2. Experimental fungicide treatments applied to established peppermint for rust control.

	Formulation										
Treatment	Conc	Unit	Type	Description	MOA	Rate		Other rate		Appl code	Mfg.
untreated											
azoxystrobin-propiconazole	2.20	lb/gal	SE	Quilt Xcel	3, 11	0.240	lb ai/a	14	oz/a	B	Syngenta
azoxystrobin-propiconazole	2.20	lb/gal	SE	Quilt Xcel	3, 11	0.240	lb ai/a	14	oz/a	A	Syngenta
+ azoxystrobin-propiconazole	2.20	lb/gal	SE	Quilt Xcel	3, 11	0.240	lb ai/a	14	oz/a	B	Syngenta
+ azoxystrobin-propiconazole	2.20	lb/gal	SE	Quilt Xcel	3, 11	0.240	lb ai/a	14	oz/a	C	Syngenta
fluxapyroxad-pyraclostrobin	4.17	lb/gal	SC	Priaxor	7, 11	0.260	lb ai/a	8	oz/a	B	BASF
fluxapyroxad-pyraclostrobin	4.17	lb/gal	SC	Priaxor	7, 11	0.260	lb ai/a	8	oz/a	A	BASF
+ fluxapyroxad-pyraclostrobin	4.17	lb/gal	SC	Priaxor	7, 11	0.260	lb ai/a	8	oz/a	B	BASF
+ fluxapyroxad-pyraclostrobin	4.17	lb/gal	SC	Priaxor	7, 11	0.260	lb ai/a	8	oz/a	C	BASF
benzovindiflupyr-azoxy-propi	2.21	lb/gal	SE	Trivapro	3, 7, 11	0.237	lb ai/a	13.7	oz/a	B	Syngenta
benzovindiflupyr-azoxy-propi	2.21	lb/gal	SE	Trivapro	3, 7, 11	0.237	lb ai/a	13.7	oz/a	A	Syngenta
+ benzovindiflupyr-azoxy-propi	2.21	lb/gal	SE	Trivapro	3, 7, 11	0.237	lb ai/a	13.7	oz/a	B	Syngenta
+ benzovindiflupyr-azoxy-propi	2.21	lb/gal	SE	Trivapro	3, 7, 11	0.237	lb ai/a	13.7	oz/a	C	Syngenta
azoxystrobin-benzovindiflupyr	45	%	WDG	Elatus	11, 7	0.205	lb ai/a	7.3	oz/a	B	Syngenta
azoxystrobin-benzovindiflupyr	45	%	WDG	Elatus	11, 7	0.205	lb ai/a	7.3	oz/a	A	Syngenta
+ azoxystrobin-benzovindiflupyr	45	%	WDG	Elatus	11, 7	0.205	lb ai/a	7.3	oz/a	B	Syngenta
+ azoxystrobin-benzovindiflupyr	45	%	WDG	Elatus	11, 7	0.205	lb ai/a	7.3	oz/a	C	Syngenta
inpyrfluxam	2.84	lb/gal	SC	Excalia	7	0.044	lb ai/a	2	oz/a	B	Valent
inpyrfluxam	2.84	lb/gal	SC	Excalia	7	0.044	lb ai/a	2	oz/a	A	Valent
+ inpyrfluxam	2.84	lb/gal	SC	Excalia	7	0.044	lb ai/a	2	oz/a	B	Valent
+ inpyrfluxam	2.84	lb/gal	SC	Excalia	7	0.044	lb ai/a	2	oz/a	C	Valent
mefentriflu-pyraclo-fluxap	3.33	lb/gal	SC	Revytek	3, 7, 11	0.390	lb ai/a	15	oz/a	B	BASF
mefentriflu-pyraclo-fluxap	3.33	lb/gal	SC	Revytek	3, 7, 11	0.390	lb ai/a	15	oz/a	A	BASF
+ mefentriflu-pyraclo-fluxap	3.33	lb/gal	SC	Revytek	3, 7, 11	0.390	lb ai/a	15	oz/a	B	BASF
+ mefentriflu-pyraclo-fluxap	3.33	lb/gal	SC	Revytek	3, 7, 11	0.390	lb ai/a	15	oz/a	C	BASF
picoxystrobin-cyproconazole	2.34	lb/gal	SC	Aproach Pri	3, 11	0.124	lb ai/a	6.8	oz/a	B	Corteva
picoxystrobin-cyproconazole	2.34	lb/gal	SC	Aproach Pri	3, 11	0.124	lb ai/a	6.8	oz/a	A	Corteva
+ picoxystrobin-cyproconazole	2.34	lb/gal	SC	Aproach Pri	3, 11	0.124	lb ai/a	6.8	oz/a	B	Corteva
penthiopyrad	1.67	lb/gal	SC	Fontelis	7	0.313	lb ai/a	24	oz/a	B	Corteva
penthiopyrad	1.67	lb/gal	SC	Fontelis	7	0.313	lb ai/a	24	oz/a	A	Corteva
+ penthiopyrad	1.67	lb/gal	SC	Fontelis	7	0.313	lb ai/a	24	oz/a	B	Corteva
+ penthiopyrad	1.67	lb/gal	SC	Fontelis	7	0.313	lb ai/a	24	oz/a	C	Corteva

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Table 3. Rust pressure and peppermint oil yield with application of experimental fungicides.

Treatment	Rate lb ai/a	Appl Code	Rust of mint Pressure 8/18/2023 0-10 scale		Peppermint Yield 8/23/2023 lb oil/a	
untreated			3.8	a	56.6	ab
azoxystrobin-propiconazole	0.240	B	2.5	abc	46.8	b
azoxystrobin-propiconazole	0.240	A	0.5	de	46.6	b
+ azoxystrobin-propiconazole	0.240	B				
+ azoxystrobin-propiconazole	0.240	C				
fluxapyroxad-pyraclostrobin	0.260	B	2.0	a-d	57.9	ab
fluxapyroxad-pyraclostrobin	0.260	A	0.3	de	56.2	ab
+ fluxapyroxad-pyraclostrobin	0.260	B				
+ fluxapyroxad-pyraclostrobin	0.260	C				
benzovindiflupyr-azoxy-propi	0.237	B	1.5	b-e	52.5	ab
benzovindiflupyr-azoxy-propi	0.237	A	0.3	de	60.9	a
+ benzovindiflupyr-azoxy-propi	0.237	B				
+ benzovindiflupyr-azoxy-propi	0.237	C				
azoxystrobin-benzovindiflupyr	0.205	B	0.8	cde	49.4	ab
azoxystrobin-benzovindiflupyr	0.205	A	0.0	e	51.3	ab
+ azoxystrobin-benzovindiflupyr	0.205	B				
+ azoxystrobin-benzovindiflupyr	0.205	C				
inpyrfluxam	0.044	B	1.0	b-e	49.7	ab
inpyrfluxam	0.044	A	0.3	de	47.4	ab
+ inpyrfluxam	0.044	B				
+ inpyrfluxam	0.044	C				
mefentriflu-pyraclo-fluxap	0.390	B	0.5	de	49.3	ab
mefentriflu-pyraclo-fluxap	0.390	A	0.5	de	57.6	ab
+ mefentriflu-pyraclo-fluxap	0.390	B				
+ mefentriflu-pyraclo-fluxap	0.390	C				
picoxystrobin-cyproconazole	0.124	B	2.8	ab	47.6	ab
picoxystrobin-cyproconazole	0.124	A	2.0	a-d	54.5	ab
+ picoxystrobin-cyproconazole	0.124	B				
penthiopyrad	0.313	B	0.5	de	52.8	ab
penthiopyrad	0.313	A	0.0	e	50.6	ab
+ penthiopyrad	0.313	B				
+ penthiopyrad	0.313	C				
LSD P=0.05			1.9		13.7	
CV			119.6		18.4	

Evaluation of Fall Application of PPO Inhibitor Herbicides in Mint

Kyle Roerig, Research Agronomist, Pratum Co-op

Introduction

PPO inhibitor herbicides, such as saflufenacil (Sharpen) and flumioxazin (Chateau) have been evaluated in previous studies and the crop safety and weed control properties of these herbicides are well established when applied to dormant mint in January and February. However, no studies have been conducted to evaluate these herbicides in the fall. The fall is an important herbicide timing because many broadleaf weeds germinate in the fall. Saflufenacil is progressing through the IR-4 process and flumioxazin is currently labeled for use in dormant mint. Up to two applications of flumioxazin are permitted by the label.

Methods

Herbicide treatments were applied to peppermint in a commercial field in Polk County, Oregon during the fall, late-fall and late-dormant season at the dates indicated in Table 1. The trial was a randomized complete block design with four replications. The treatments were applied using a compressed air bicycle-wheel sprayer using Greenleaf AM 11003 nozzles calibrated to deliver 20 gallons per acre. The trial was conducted in a double-cut field, but the trial was only carried through the first cutting. The plots were swathed with a research plot swather June 27, 2023, and chopped June 29. Harvested peppermint was distilled the following day.

Results

At the December 29, 2023, evaluation of the plots, all plots exhibited 80 percent or greater crop injury and 95 percent or greater control of common groundsel (data not shown). By mid-February, just prior to the final application timing, all plots were showing 95 percent injury (Table 3). Groundsel control was 100 percent with all saflufenacil treatments. Plots treated with flumioxazin achieved 83-100 percent control of groundsel. Sowthistle was also controlled by saflufenacil at each timing. Flumioxazin only controlled sowthistle when applied in the fall and late dormant season. Fall application of oxyfluorfen provided 100 percent control of all three weed species. By mid-May the early applications of saflufenacil and all applications of flumioxazin were exhibiting 30-75 percent injury. Despite high injury ratings 40 days prior to harvest, no treatments reduced oil yield. These results indicate that injury visible in the winter and spring with these types of treatments is unlikely to reduce yield.

Table 1. Crop information and treatment application timing.

Site Description	
Crop	Peppermint
Variety	Blue mountain
Stand age	Fifth year
Soil	Amity silt loam
Location	44.806890, -123.174281

Application	A	B	C
Date	10/20/2022	11/28/2022	2/17/2023
Start Time	1:20 PM	10:30 AM	1:30 PM
Stop Time	1:50 PM	11:20 AM	1:50 PM
Applied By	KCR	KCR	KCR
Air Temperature	71 F	48 F	52 F
Relative Humidity	54	75	55
Wind Velocity+Dir.	1 MPH	4-5 MPH, SSW	2-4 MPH, S
Wet Leaves (Y/N)	No	Yes	No
Soil Temperature	66 F	43 F	46 F
Soil Moisture	dry	wet	wet
% Cloud Cover	25	80	10
Crop	3-6 inch regrowth	Dormant	Dormant

Table 2. PPO inhibitor herbicides applied to peppermint in the fall, late-fall and dormant season.

Treatment	Formulation Conc		Formulation Type	Description	Rate		Code	Description
untreated								
saflufenacil	2.85	lb/gal	SC	Sharpen	2	oz/a	A	mid-Oct
+ MSO	100	%	L		1	% v/v	A	mid-Oct
+ AMS	100	%	L	AMStrike	1	% v/v	A	mid-Oct
saflufenacil	2.85	lb/gal	SC	Sharpen	4	oz/a	A	mid-Oct
+ MSO	100	%	L		1	% v/v	A	mid-Oct
+ AMS	100	%	L	AMStrike	1	% v/v	A	mid-Oct
saflufenacil	2.85	lb/gal	SC	Sharpen	2	oz/a	B	late-Nov
+ MSO	100	%	L		1	% v/v	B	late-Nov
+ AMS	100	%	L	AMStrike	1	% v/v	B	late-Nov
saflufenacil	2.85	lb/gal	SC	Sharpen	4	oz/a	B	late-Nov
+ MSO	100	%	L		1	% v/v	B	late-Nov
+ AMS	100	%	L	AMStrike	1	% v/v	B	late-Nov
flumioxazin	51	%	WDG	Chateau	4	oz/a	A	mid-Oct
+ NIS	100	%	L		0.25	% v/v	A	mid-Oct
flumioxazin	51	%	WDG	Chateau	4	oz/a	B	late-Nov
+ NIS	100	%	L		0.25	% v/v	B	late-Nov
flumioxazin	51	%	WDG	Chateau	4	oz/a	A	mid-Oct
+ NIS	100	%	L		0.25	% v/v	A	mid-Oct
flumioxazin	51	%	WDG	Chateau	4	oz/a	C	Dormant
+ NIS	100	%	L		0.25	% v/v	C	Dormant
flumioxazin	51	%	WDG	Chateau	4	oz/a	B	late-Nov
+ NIS	100	%	L		0.25	% v/v	B	late-Nov
flumioxazin	51	%	WDG	Chateau	4	oz/a	C	Dormant
+ NIS	100	%	L		0.25	% v/v	C	Dormant
oxyfluorfen	2	lb/gal	EC	Galigan 2E	1	pt/a	A	mid-Oct
+ NIS	100	%	L		0.25	% v/v	A	mid-Oct

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Table 3. Weed control and crop safety of PPO inhibitor herbicides applied to peppermint in the fall and dormant season.

Treatment	Rate		Appl	Injury Peppermint 2/17/2023	Control groundsel 2/17/2023	Injury Peppermint 5/19/2023	Control Sowthistle 5/19/2023	Control Prickly lettuce 5/19/2023	Yield Peppermint 6/29/2023
				------------	------------	------------ % ------------	------------	------------	lb oil/a
untreated				0 b	0 c	0 g	0 c	0 c	54.5 -
saflufenacil	2	oz/a	A	95 a	100 a	68 abc	100 a	100 a	62.3 -
+ MSO	1	% v/v	A						
+ AMS	1	% v/v	A						
saflufenacil	4	oz/a	A	95 a	100 a	75 ab	100 a	98 a	67.7 -
+ MSO	1	% v/v	A						
+ AMS	1	% v/v	A						
saflufenacil	2	oz/a	B	95 a	100 a	15 fg	100 a	25 bc	70.5 -
+ MSO	1	% v/v	B						
+ AMS	1	% v/v	B						
saflufenacil	4	oz/a	B	95 a	100 a	5 g	100 a	43 b	60.8 -
+ MSO	1	% v/v	B						
+ AMS	1	% v/v	B						
flumioxazin	4	oz/a	A	95 a	83 b	55 bcd	88 ab	100 a	71.8 -
+ NIS	0.25	% v/v	A						
flumioxazin	4	oz/a	B	95 a	100 a	30 ef	88 ab	78 a	63.9 -
+ NIS	0.25	% v/v	B						
flumioxazin	4	oz/a	A	95 a	100 a	78 a	100 a	100 a	59.8 -
+ NIS	0.25	% v/v	A						
flumioxazin	4	oz/a	C						
+ NIS	0.25	% v/v	C						
flumioxazin	4	oz/a	B	95 a	89 ab	48 cde	75 b	100 a	66.8 -
+ NIS	0.25	% v/v	B						
flumioxazin	4	oz/a	C						
+ NIS	0.25	% v/v	C						
oxyfluorfen	1	pt/a	A	95 a	100 a	35 def	100 a	100 a	61.5 -
+ NIS	0.25	% v/v	A						
LSD P=0.05				.	11	20	20	27	20.4
CV				0	9	34	16	25	21.9

The Mint Pest Alert Newsletter Celebrates 10 Years

Christy Tanner, Darrin L. Walenta and Jeremiah Dung, Oregon State University

Project Overview

The mint pest alert newsletter was started in 2014 with the goal of helping mint growers make the best use of a new insecticide Coragen (now also called Vantacor) for the management of mint root borer, cutworms and loopers. This product is effective against the eggs and larvae of moths, while being safer for pollinators and other beneficial insects than other products used on mint at the time. Coragen is a systemic product that is absorbed by plant tissues and provides residual control for up to two weeks. This product is most effective on eggs and small larvae. These characteristics mean that Coragen can be very effective against several problematic mint pests, if the spray is applied at the optimal time. The mint pest alert newsletter was designed to help growers optimize the timing of their spray applications so that they can get the best possible control of these pests.

The Pest Alert Newsletter combines information from growing degree-day models and weekly monitoring of commercial mint fields in three regions in Oregon: Willamette Valley, Central Oregon and Northeast Oregon. Growing degree-day (GDD) models for both mint root borer (MRB) and variegated cutworm were run for five weather stations across Oregon, one in the Willamette Valley, two for Central Oregon and two for Northeastern Oregon to ensure that growers were receiving locally relevant information. In-field monitoring included pheromone traps, sweep net samples and visual scouting, which helped verify the accuracy of the models.

In addition to distributing the newsletter during the 2023 crop year, a web application was developed. The app will make growing degree information available to growers and agronomists in real time. Information about the new app was shared at the Oregon Mint Growers meeting in January 2024 and the app will be in use for the 2024 growing season.

Activities

Newsletter Distribution

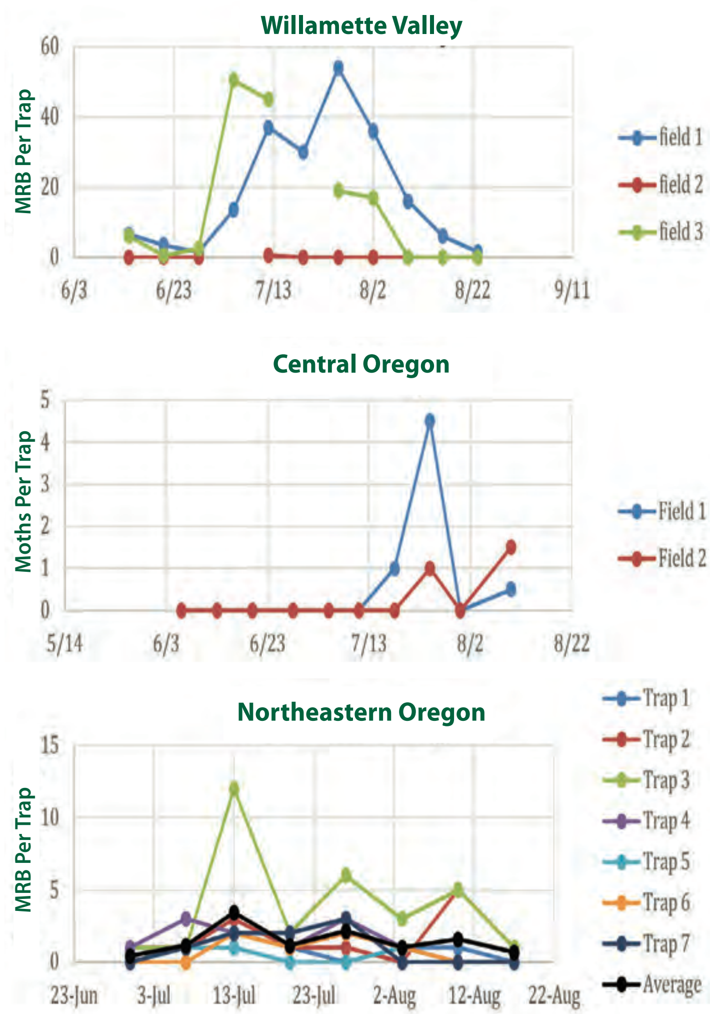
The newsletter was distributed using the Mailchimp platform. This year there were 57 recipients in Western Oregon, 22 in Central Oregon and 52 in Northeastern Oregon. In addition to the email version of the newsletter, model updates and field observations were made available on the Mint Pest Alert website (http://blogs.oregonstate.edu/mintpestalert), along with general information about mint pests and their management.

Scouting and Monitoring

Three commercial mint fields were monitored in the Willamette Valley, two fields in Central Oregon and four fields in Northeastern Oregon. Two pheromone traps were placed in each field starting in May and June. Each week the traps we checked for MRB and cutworm moths and the sticky cards were replaced. Sweep net samples were collected when traps were checked to monitor for loopers and variegated cutworm larvae.

Compared to the 2022 growing season, 2023 was considerably warmer, with GDD accumulations running only slightly behind those of 2021. MRB moth counts were similar to last year for the Willamette Valley, but lower in Central and Northeastern Oregon. Trap captures did not match model predictions as well as in past years. In the Willamette Valley, MRB captures in one field peaked three weeks later than predicted by the model, while another field was consistent with the model (Figure 1). Average captures could not be calculated for all weeks because of missing data (e.g. traps could not be checked due to insecticide

Figure 1. Timeseries of MRB moth counts from traps in the Willamette Valley (top), Central Oregon (middle) and Northeastern Oregon (bottom).



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applications or first cuttings), but appeared to peak one week after model predictions. Trap captures in Central Oregon were low for the first part of the season. Peak moth catch was observed two weeks later than the model predicted. In Northeastern Oregon, MRB numbers were fairly consistent throughout the season and peak catch occurred very close to the model prediction.

Growing Degree Day Web App

A web application was developed to display up to date growing degree accumulation for both mint root borer and variegated cutworm. Users can select from five weather stations and any of four forecasting methods for GDD predictions. The date range can also be adjusted to see a different portion of the season. The app can be found on each region page on the Mint Pest Alert blog site at https://blogs.oregonstate.edu/mintpestalert, or by visiting https://kctanner.shinyapps.io/MintShinyApp. A screenshot of the app is shown in Figure 2.

Survey Results

The end of year evaluation survey received 12 responses, but only 6 respondents completed all questions on the survey. As usual, support for continuing this project was high, with 9 of 10 respondents responding “Yes.” Knowledge about insect development based on degree-days increased by 0.57 points on a five point scale, and knowledge about the use of Coragen/Vantacor insecticide increased by 0.71 points (Table 1). Respondents rated the amount of influence the newsletter had on their decisions about insecticide timing and product choice and this year’s responses were consistent with previous years (Table 2).

Table 1. Newsletter recipient knowledge level of insect development based on DD and the use of Coragen®, before and after reading the e-Newsletter (1=uninformed, 5=fully informed).

	Insect Development	Use of Vantacor/Coragen
Before	3.3	3.0
After	3.9	3.7

Table 2. Influence of Newsletter on insecticide application timing and insecticide product choice (1= no influence, 5= heavy influence), for 2019-2023.

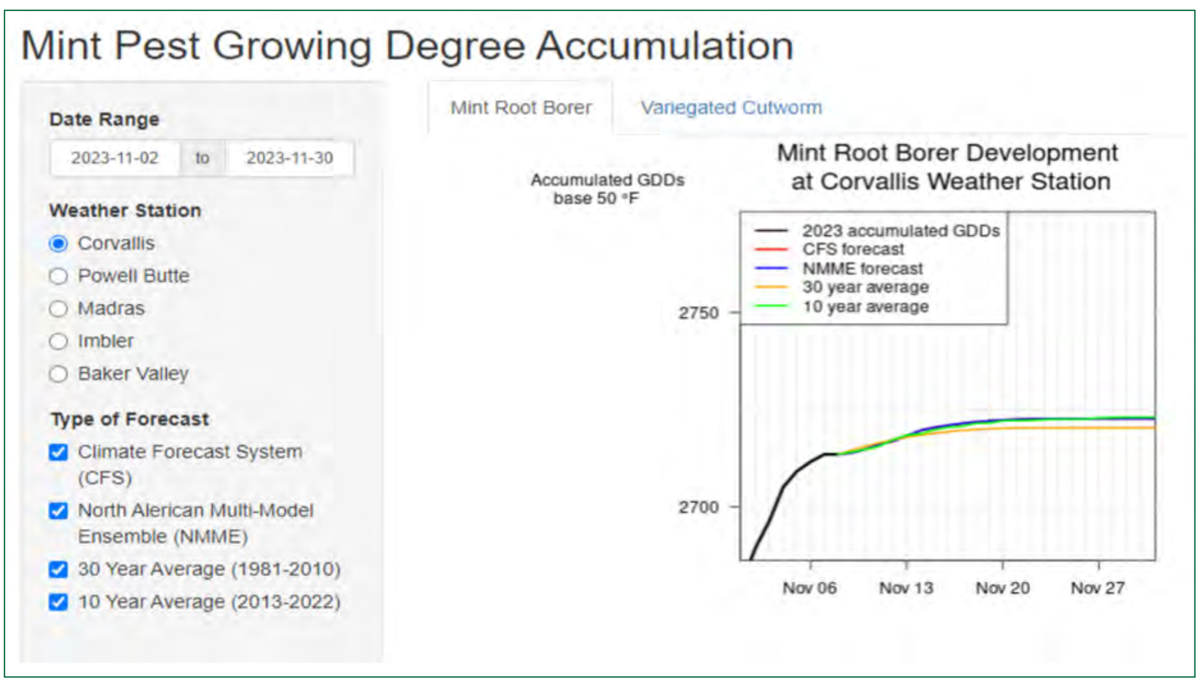
	Insecticide Timing	Product Choice
2019	3.1	3.2
2020	2.9	2.9
2021	3.0	3.0
2022	3.8	3.6
2023	**3.2**	**3.5**

Respondents also reported a number of benefits of the project including better pest control, time saved, reduced pesticide use and an increased willingness to use or recommend Vantacor. When asked about the financial impact of the Mint Pest Alert, four respondents answered with answers ranging from $0 to $80 saved per acre. However, only one of these responses ($80) came from a grower.

Acknowledgements

Thank you to the Oregon Mint Commission for their support of this project and all of the growers who allowed access to their fields for local scouting efforts.

Figure 2. The Mint Pest Growing Degree App.



Mint Industry Research & Regulatory Update

Steve Salisbury, Mint Industry Research Council Research and Regulatory Coordinator

The MIRC is pleased to announce that Velum Prime has been labeled for use in mint for nematode control. Bayer Crop Science has completed the registration and labeling process with the help of IR-4. Growers can begin using Velum Prime this growing season. It is always exciting to get a new tool in the IPM box for growers to utilize.

This new label is also a result of several years of research investment by the MIRC. The MIRC funded research with Dr. Saad Hafez at the University of Idaho Parma R & E Center to evaluate the effectiveness of fluopyram (Velum Prime) on nematodes affecting mint. This research was key in supporting this new label and we appreciate the diligence by Dr. Hafez and his team, as well as Bayer's support of mint.

The use pattern is fairly similar to the industry's longtime stand-by Vydate. So, hopefully growers can begin incorporating Velum Prime into their program with some degree of ease. The product can be applied at a rate of 6.0 – 6.4 fl oz per acre per application. There is a maximum of two applications per season, with a minimum interval of 21 days between applications. It can be applied by ground or with chemigation. There should be ½ to ¾ inch of precipitation/irrigation applied within one hour following the application. The pre-harvest interval is 28 days.

Having a new option for nematodes allows for multiple products to be used. Velum Prime can be used in conjunction with your typical Vydate application(s) if needed. Depending on the specific situation in the field, you can begin from dormancy break to post-harvest and in between as needed. As always, it is important to know your specific situation. And keep in mind, controlling nematodes in mint will also have a positive influence on the development and severity of *verticillium* wilt in mint fields.

Steve Salisbury

We continue to pursue a label for the use of Spartan between cuttings. In 2023 we were only able to get approval of 24C SLN labels in Oregon and Idaho. All the other states were requested at the same time, but they were not willing or able to approve the request. We are again working with the registrant, FMC, to obtain the state's approvals for 2024. Discussions are underway and we hope that the request can successfully work its way through the process. At the same time, we are awaiting the EPA to approve the revised full label to include use between cuttings. There is no timeline as to when that decision/approval will be, hence the request for SLNs from the states.

The 2024 MIRC research program was presented and approved by the Board of Directors in January. The MIRC continues to address needs in our four areas of priority for the industry. The projects funded include integrated pest management work on *verticllium*, weeds and entomology. Cultivar development and genetics research is going to continue. Agronomic and sustainability projects include the progression of the nitrogen fertilizer in spearmint and a distillation study. Our members continue to be supportive of the sensory work with mint to help find new opportunities for the use of mint oil.

Each year the Scientific Affairs Committee and Board of Directors thoroughly discuss all the projects proposed to them for funding consideration. These folks do an excellent job at identifying projects that address our industry's needs while working to ensure that the value from these funded projects is attainable by all of the MIRC members. This is in part what makes the MIRC special, with our members representing the entire value chain of the mint industry. While some topics seem straightforward to support, some may not be fully realized by others. The MIRC provides the opportunity for everyone to voice their perspective on the research while also looking out for the best interest of the industry. We appreciate all of the input, feedback, additional funding, in-kind support and leadership by all of the members. That is truly what it takes to conduct an effective research program for the industry.

That said, I always encourage everyone to share their thoughts, comments or suggestions on current or needed work to be done on mint. Please feel free to reach out to me or your board member representative and share your thoughts. I wish everyone a safe and profitable 2024 crop year.

Phosphite Sensitivity of *Verticillium dahliae* Isolates from Mint

Lauren Papke, Jeness Scott and Jeremiah Dung, Central Oregon Agricultural Research and Extension Center, Oregon State University

Verticillium wilt is a serious soilborne disease that negatively impacts U.S. mint production. Due to its wide host range and long survival in soil, crop rotation is largely ineffective and control options are limited. Once the pathogen is established in a field, management options for *Verticillium* wilt in mint are even more restricted. Although soil fumigation can reduce *Verticillium dahliae* populations in the soil, it is not a sustainable or a viable long-term solution. Integrated pest management (IPM) based strategies for *Verticillium* wilt on mint are needed to enable sustainable mint production in the United States.

Phosphites are salts (anions) of phosphorous acid (H_3PO_3) and represent a class of chemicals that are effective in suppressing the development of various diseases caused by oomycetes such as *Phytophtora infestans*, the causal agent of potato late blight. Several studies have concluded that phosphite-based fungicides are systemic fungicides and reduce plant disease by direct interactions between phosphite and pathogens and/or initiating plant immune responses. Phosphites are considered to be environmentally friendly because they can be degraded to naturally-occurring phosphates by soil microorganisms that harbor the enzyme phosphite dehydrogenase.

Phosphites have also shown an inhibitory effect on certain fungal pathogens including *Fusarium*, *Rhizoctonia* and, more recently, *Verticillium*. Direct inhibition of oomycetes in plants typically requires concentrations of at least 100 µg/ml. Previous research has found that the half maximal inhibitory concentration for some species of *Verticillium* ranged from 60.9 to 481.9 µg/ml, suggesting that some isolates may be responsive to applications

of phosphite. The same study also observed significantly reduced infection progression in potato after applications of phosphite. However, the aforementioned research only screened a limited number of *Verticillium* isolates and more information is needed to determine if phosphites offer a potential IPM approach towards *Verticillium* wilt management in mint.

The inhibitory effect of phosphites on the mycelial growth of 20 isolates of *V. dahliae* from peppermint (n = 17), Scotch spearmint (n = 1), native spearmint (n = 1) and potato (n = 1) was evaluated on potato dextrose agar (PDA) amended with Reliant Systemic Fungicide (Quest Products LLC, Lindwood, KS), which contains 45.8 percent (w/w) mono- and di-potassium salts of phosphorous acid. Mycelial plugs (4 to 7 mm in diameter) were excised from the edge of 7 to 14 day-old fungal colonies and placed mycelia side down onto PDA amended with phosphite at a concentration of 0.0 (control), 0.1, 0.5 or 1.0 mg/ml. Plates were maintained at 20 to 23 °C in the dark. The diameter of each colony was measured in two perpendicular directions at 7-, 14- and 21-days post-plating and mycelial growth rates were calculated. Each isolate and treatment combination was replicated three times and the experiment was conducted twice.

Relative growth rates were calculated by dividing the colony size for each isolate in the presence of phosphite by the colony size in the non-amended control treatment, with values closer to 1 indicating greater resistance and values closer to 0 indicating greater sensitivity. A value < 0.5 was used as the boundary to indicate phosphite sensitivity. The effects of isolate, phosphite concentration and their interaction were assessed using analysis of variance.

A significant effect of isolate, phosphite dose and their interaction was observed for relative colony size ($P < 0.0001$). The mean relative growth rate for all isolates grown in media amended with 1.0 mg/ml phosphite were significantly less than the mean relative colony size when the same isolates were grown in media without phosphite, with the exception of four isolates (Table 1). Although none of the isolates exhibited a mean growth reduction less than the predetermined threshold of 0.5, potential future research efforts may focus on applying phosphites directly to peppermint plants with the intention of initiating plant defense responses in the crop and reducing the incidence or severity of *Verticillium* wilt.

Table 1. Relative growth rates of *Verticillium dahliae* isolates plated onto media amended with 0-, 0.1-, 0.5- or 1.0 mg/ml of phosphite (Reliant Systemic Fungicide; 45.8 percent (w/w) mono- and di- potassium salts of phosphorous acid).

					Phosphite concentration			
Isolate	**Host**	**Location**	**State**	**Year**	**0 mg/ml**	**0.1 mg/ml**	**0.5 mg/ml**	**1.0 mg/ml**
M-53	Native spearmint	Unknown	WA	1996	1.00	0.93	0.71	0.60*
M-129	Scotch spearmint	Unknown	WA	1996	1.00	0.93	1.21	0.81*
M-111	Peppermint	Unknown	WA	1996	1.00	1.02	0.93	0.78*
M-152	Peppermint	Unknown	ID	1996	1.00	0.94	0.67	0.54*
1118	Peppermint	Unknown	MT	Unknown	1.00	0.92	0.74	0.61*
1130	Peppermint	Jefferson Co.	OR	2000	1.00	0.93	1.09	1.01
14-197	Peppermint	Jefferson Co.	OR	2014	1.00	0.94	0.74	0.68*
14-199	Peppermint	Jefferson Co.	OR	2014	1.00	0.89	0.72	0.57*
14-203	Peppermint	Jefferson Co.	OR	2014	1.00	0.89	0.71	0.57*
15-014	Peppermint	Jefferson Co.	OR	2015	1.00	0.93	0.73	0.55*
15-024	Peppermint	Jefferson Co.	OR	2015	1.00	1.00	0.83	0.79*
15-054	Peppermint	Jefferson Co.	OR	2015	1.00	1.10	0.98	0.93
1106	Peppermint	Union Co.	OR	2006	1.00	1.08	0.89	0.85*
15-080	Peppermint	Union Co.	OR	2015	1.00	1.05	0.90	0.83*
1126	Peppermint	Willamette Valley	OR	2000	1.00	1.02	1.01	0.96
15-034	Peppermint	Willamette Valley	OR	2015	1.00	0.90	0.67	0.56*
15-059	Peppermint	Willamette Valley	OR	2015	1.00	0.94	0.77	0.65*
15-063	Peppermint	Willamette Valley	OR	2015	1.00	0.96	0.77	0.62*
15-064	Peppermint	Willamette Valley	OR	2015	1.00	1.15	1.15	0.98
653	Potato	Unknown	ID	1995	1.00	0.93	0.99	0.73*

* Indicates a significant difference in relative colony size compared to the same isolate grown in the absence of phosphite (0 mg/ml).

Optimizing Nitrogen Application for Mint in the Columbia Basin

Ruijun Qin, Oregon State University; Rui Liu & Troy Peters, Washington State University

Ensuring the optimal application of nitrogen (N) is crucial for enhancing grower profitability and minimizing the risk of N losses when cultivating native spearmint. The current recommended N rates of 200-250 lb/a were established over four decades ago, primarily based on rill (furrow) irrigated fields. However, these fields often experience significant N and water losses. Given that center pivot irrigation systems have become the predominant method for mint production, it is evident that the existing fertilizer recommendations may be excessive for this more efficient irrigation approach. Therefore, a revision of the N recommendations is warranted.

Our recent field trials on spearmint showed that a reduced N rate of 150 lb/a can generate comparable oil yields to the traditional N rate (200 lb/a), albeit with a lower hay yield. In practical field applications, growers adopt varying N application strategies – some apply all upfront, while others opt for split applications, distributing them in the spring and after the first summer cutting. Therefore, it is essential to conduct further field trials for comprehensively understanding the optimal N rate and timing. In 2023, we carried a field trial in the established research field utilizing a linear-move irrigation system, similar to a center pivot. The anticipated research findings will play a pivotal role in updating existing mint growth guidelines. By providing growers with more accurate information, these guidelines aim to enhance efficiency in mint oil production, reduce N fertilization input costs and mitigate environmental hazards associated with excessive N application.

Material and Methods

In the fall of 2018, a comprehensive native spearmint trial was initiated and the mint roots were planted with a row spacing of 76 cm and a planting depth of 15-20 cm at the Washington State University-Irrigated Agriculture Research and Extension Center (IAREC) near Prosser, WA (46°15’09.3”N, 119°44’16.7”W). The study area, characterized by silt loam soil, aimed to identify optimal irrigation and N rates. Based on the results from previous years and grower recommendations, the experimental design was modified in 2023 to include 18 treatments, combining six N rates and three N application timings. The field trial followed to a randomized complex block design with three replicates, resulting in 54 plots, each measuring 20 ft x 30 ft.

N application timings included:

- (T1) All N in the spring and none after the first cutting
- (T2) 1/2 of N in the spring and 1/2 after the first cutting
- (T3) 2/3 of N in the spring and 1/3 after the first cutting

N application rates included:

- (R1) 250 lb/a
- (R2) 200 lb/a
- (R3) 150 lb/a
- (R4) 100 lb/a
- (R5) 50 lb/a
- (R6) 0 lb/a

Moreover, within the non-fertilization plots, a designated portion (5 ft x 30 ft) was allocated for additional N fertilization tests. Three types of fertilizers, namely SuperU (46-0-0), Multi-cote (41-0-0) and ammonium sulfate, were included. The fertilization regimen, based on an N rate of 100 lb/a, involved spring applications for SuperU and Multi-cote, while ammonium sulfate was applied five times throughout the crop season. In total, nine small-plots were set up near the left side of the non-fertilizer control (R3).

Harvesting occurred twice, on June 28 and Sept 6, for both the 54 main plots and the nine small plots. Each plot was individually harvested and distilled to obtain mint hay yields (lbs per acre) and oil yields (fl oz per acre).

Throughout the crop season, continuous monitoring of leaf nutrient content, soil nutrient content and leaf greenness was conducted at the treatment of T1 and T3. Approximately 50 fully developed leaves were regularly sampled within each plot, and leaf greenness was assessed with a SPAD chlorophyll meter

(Konica–Minolta, Inc., Osaka, Japan). Soil samples were taken monthly at depths of 0-15 cm and 15-30 cm. The integration of hay and oil yield data aims to determine critical leaf and soil nutrient levels associated with optimal hay and, especially, oil production. This comprehensive approach ensures a thorough evaluation of the factors influencing native spearmint growth and productivity throughout the trial period.

Results:

Mint Hay Yield: Figure 1 displays hay yields for the 1st and second cuttings. In the first cutting with all spring-applied N (T1), higher yields correlated with increased N rates, particularly at 250 lb/a (R1). However, when N was split between spring and post-2nd cutting (T3), no significant difference in hay yield was observed. Overall, the hay yields at the second cutting were lower due to cooler temperatures and shorter growing days. Notably, split applications (T3) consistently outperformed the single application (T1) in hay production.

Mint oil production: Figure 2 illustrates mint oil production in the study. Generally, oil production from the first cutting exceeded that of the second cutting. When all N was applied in the spring, oil production correlated with the N amount, but no significant differences were found among the six N rates. This pattern was consistent in T3, where 2/3 of the nitrogen was applied in the spring and 1/3 after the first cutting.

Mint leaf nutrient contents: Mint leaf samples were collected three times (May 23, June 6 and June 27) before the first cutting and twice (August 14 and September 1) before the second cutting. The leaf nitrogen (N) concentration increased from the first (May 23) to the second (June 6) sampling, followed by a decline (Figure 3). The leaf N concentration after the first cutting generally remained consistent. Overall, leaf N concentration correlated with N rates; higher N rates yielded higher leaf N concentrations, while plots with no N input had the lowest leaf N concentration.

Figure 1. The hay yield under the different N fertilization methods (T1- all N in the spring and none after the first cutting; T3-2/3 of N in the spring and 1/3 after the first cutting) and rate (R1- R6, 250-0 lb/a).

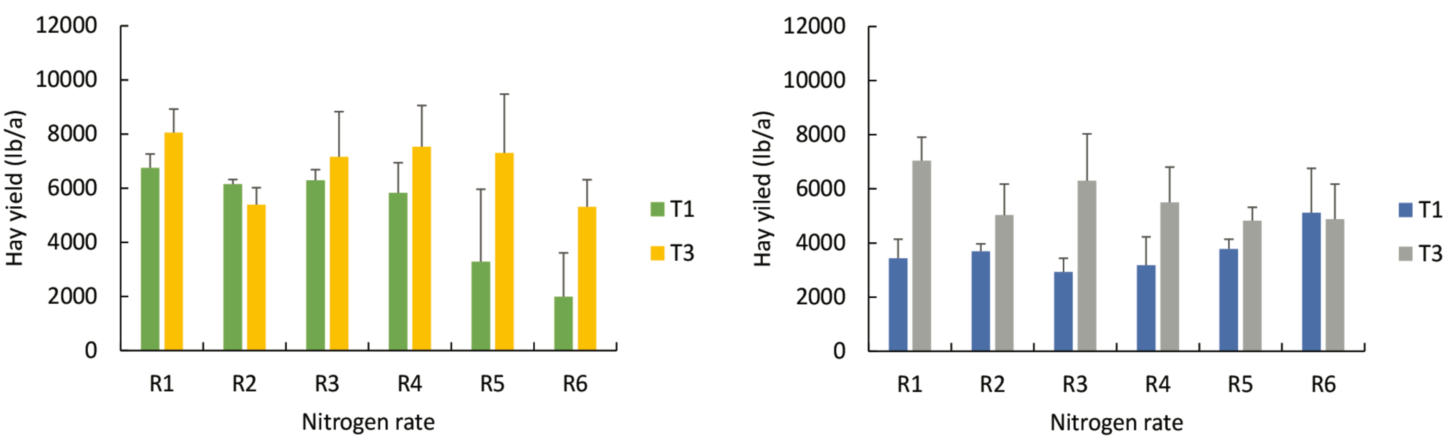


Figure 2. Mint oil production under the different N fertilization methods (T1- all N in the spring and none after the first cutting; T3-2/3 of N in the spring and 1/3 after the first cutting) and rate (R1- R6, 250-0 lb/a).

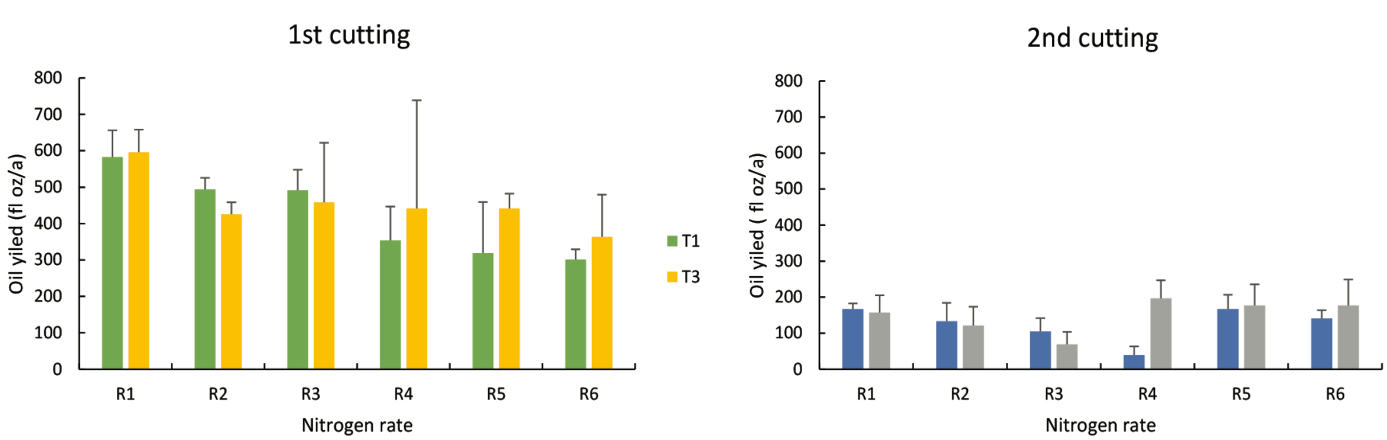


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Figure 3. Mint leaf N concentration under the different N fertilization methods (T1- all N in the spring and none after the first cutting; T3-2/3 of N in the spring and 1/3 after the first cutting) and rate (R1- R6, 250-0 lb/a).

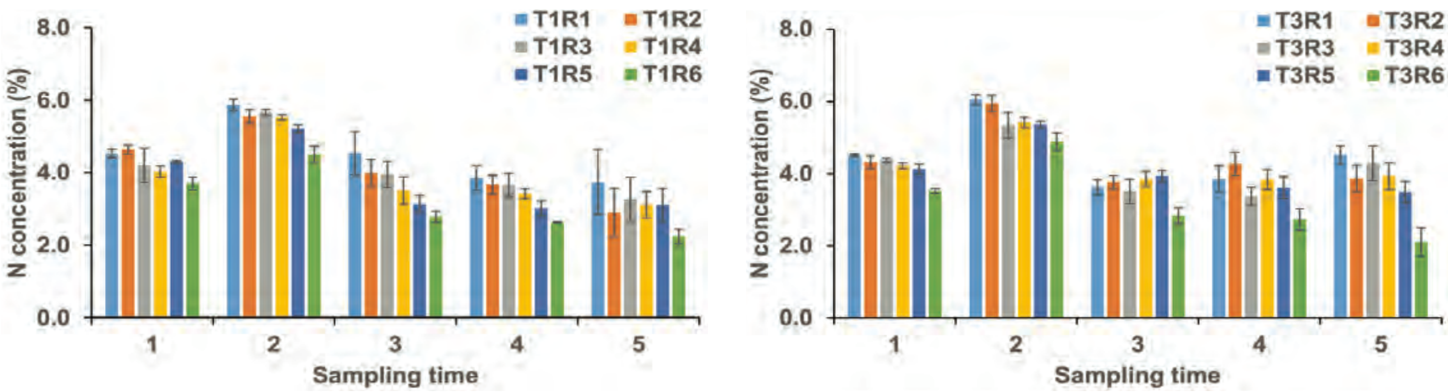
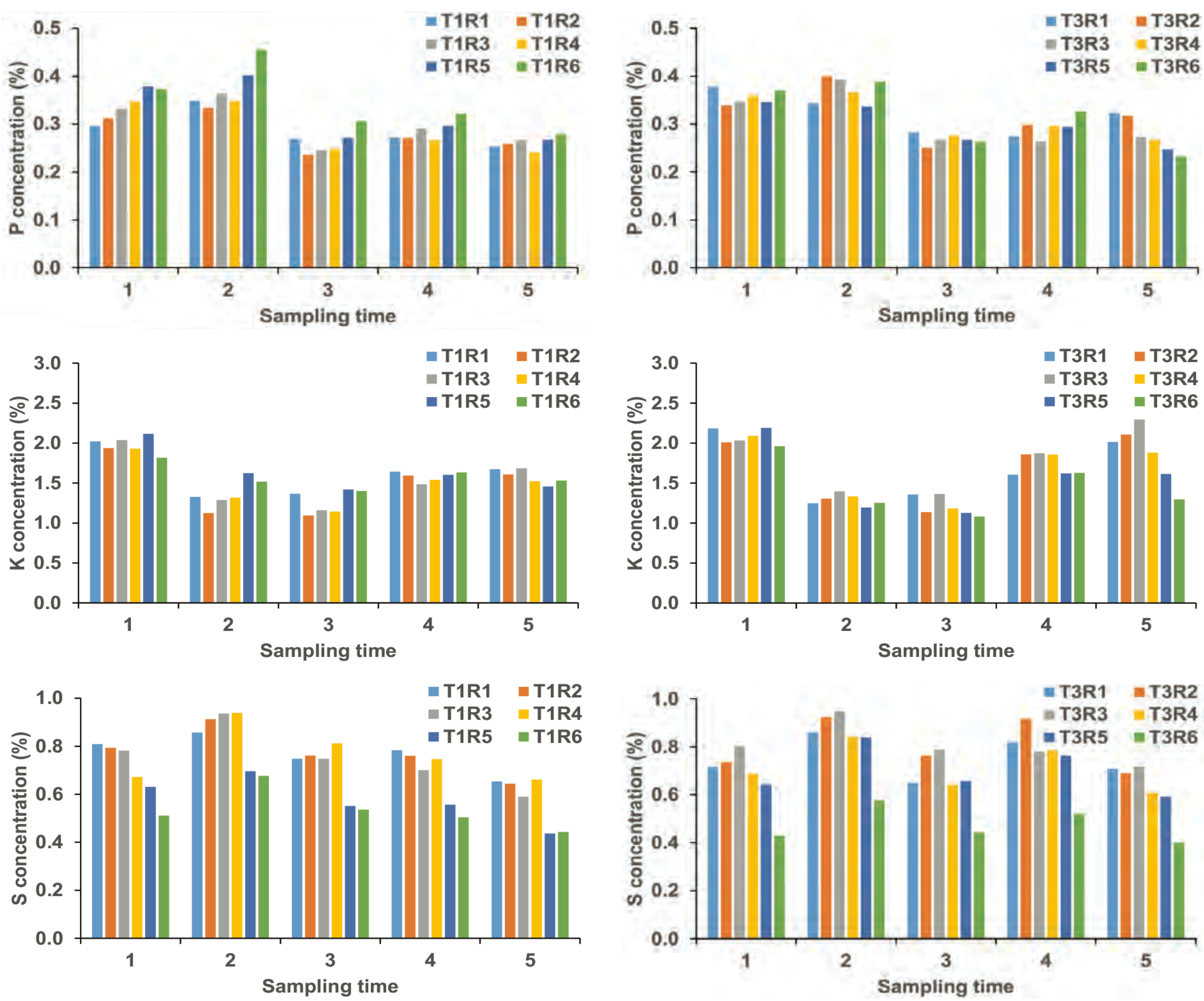


Figure 4. Mint leaf P, K and S concentration under the different N fertilization treatments (T1- all N in the spring and none after the first cutting; T3-2/3 of N in the spring and 1/3 after the first cutting) and rate (R1- R6, 250-0 lb/a).



The leaf phosphorus (P) concentration (%) showed an increase from the initial sampling on May 23 to the second sampling on June 6. Subsequently, the leaf P concentration decreased but remained stable throughout the season (Figure 4). Specifically under T1, P concentrations tended to decrease with increasing N application rates, particularly during the early sampling period. However, no distinct pattern was observed under T3 for P concentrations. No clear pattern was identified in mint potassium (K) concentration (Figure 4). However, mint leaf sulfur (S) concentration exhibited an association with S input, indicating that higher S input led to increased S concentration in the leaves (Figure 4).

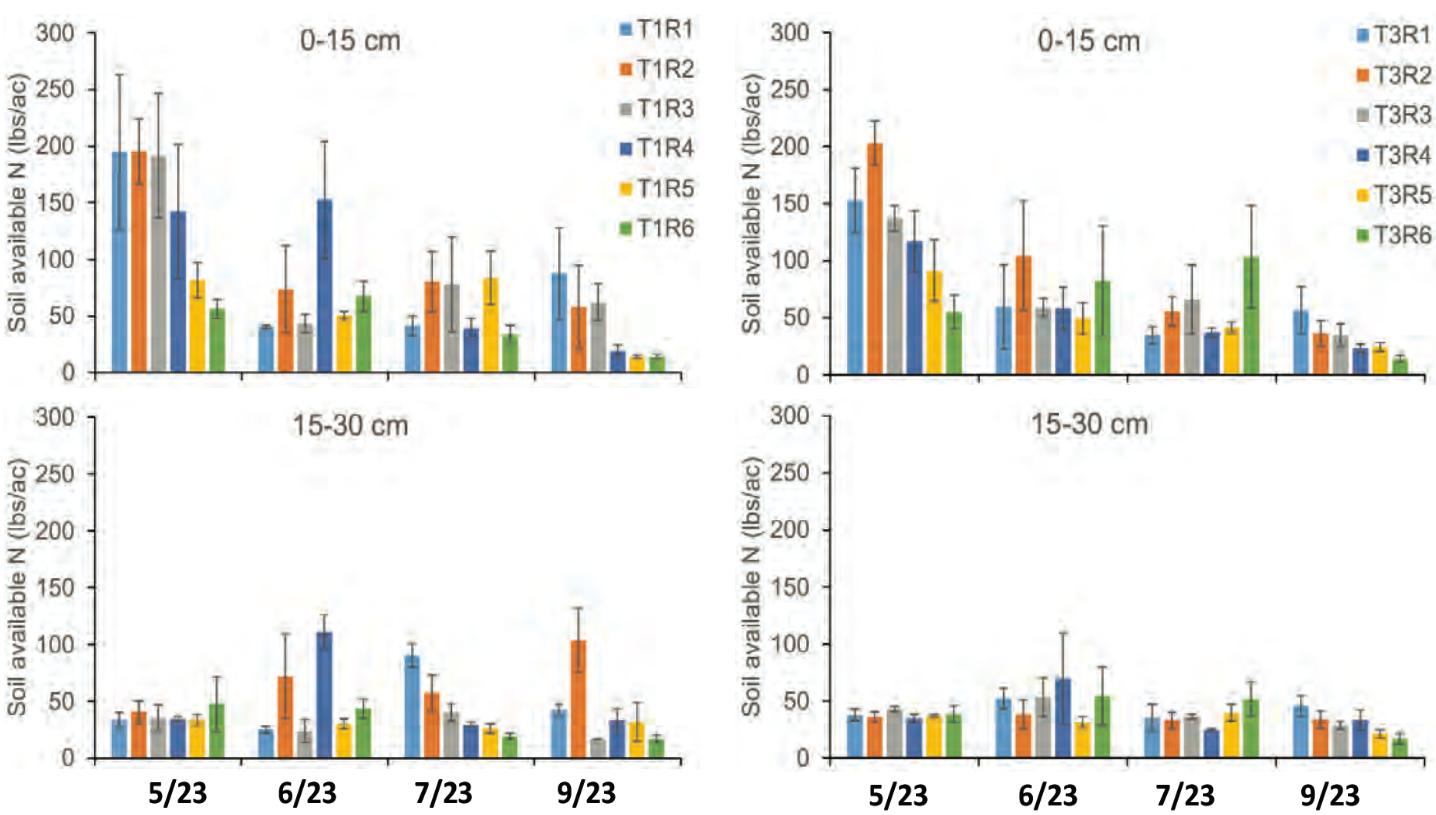
Soil nutrient contents: Soil N content was assessed twice before the first cutting (May 23 and June 23), once after the first cutting (July 23), and once after the second cutting (September 23). Notably, N content was consistently higher at the 0-15 cm soil depth compared to 15-30 cm (Figure 5). For both T1 and T3, the highest N content was observed during the first sampling, followed by a gradual decrease as the season progressed. Under T1 at the initial sampling, the soil N content peaked at the N rate of 150-250 lb/a, with subsequent decreases at lower N rates. Differences among N rates were less pronounced in subsequent samplings, echoing a similar pattern under T3.

Higher soil phosphorus (P), potassium (K) and sulfur (S) contents were also noted at the 0-15 cm depth compared to 15-30 cm (data not shown), although clear stratification was not evident. Despite the expectation of stratification for soil P, likely due to its immobility, this study did not observe such stratification. This could be attributed to the sandy soil composition and an ample nutrient supply in the surface soil (0-30 cm). Consequently, future soil sampling efforts may not necessitate multiple depths, considering the lack of stratification in this study.

Soil pH exhibited lower values at the 0-15 cm depth compared to 15-30 cm, particularly notable during the initial sampling (Figure 6). Additionally, it was observed that soil pH under the highest N rate was lower than at lower N inputs or the non-fertilization control, especially in the early sampling period. This could be attributed to the acidification effect of ammonium sulfate. Soil organic matter content remained around 2 percent regardless of soil depth (data not shown).

Mint leaf greenness: The mint leaves greenness was measured three times before the first cutting and two times after the first

Figure 5. Soil N content under the different N fertilization methods (T1- all N in the spring and none after the first cutting; T3-2/3 of N in the spring and 1/3 after the first cutting) and rate (R1- R6, 250-0 lb/a).



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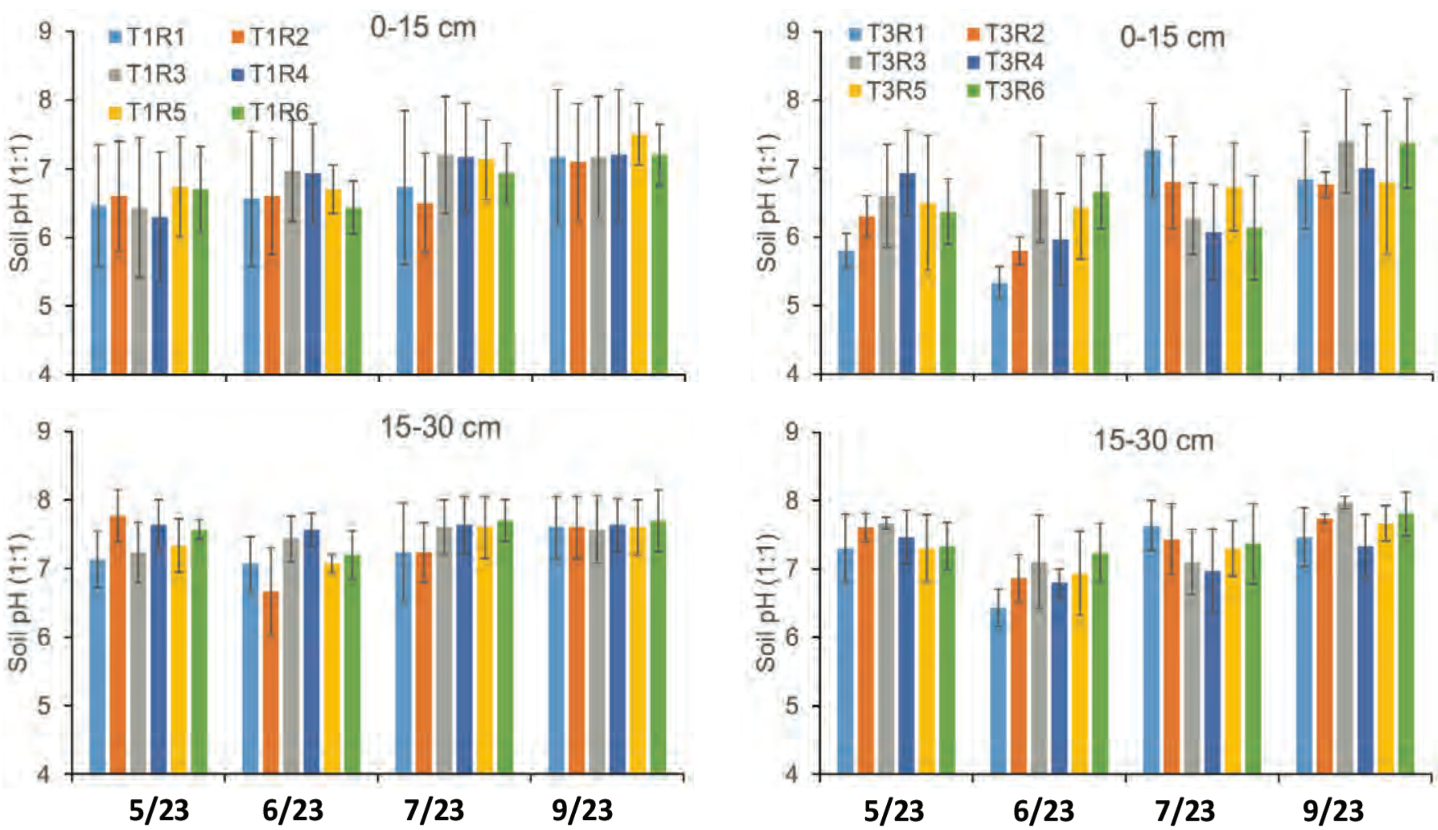
cutting. The leaf greenness increased from the first measurement to the second one because of the N application (Figure. 7). After that, it gradually decreased as the season progressed. The leaf greenness decreased with the lower N rate, especially during the late growing stage, regardless of the fertilization methods.

Results from the small plot observation: Figure 8 showed the comparison between the data from the small plots and the selected treatments from the main plots such as T1R4 or T3R4. All of them received the N rate of 100 lb/a. In general, both hay production and oil yield were higher from first cutting than the second cutting. At the first cutting, the 5-time split application had the highest hay yield followed by SuperU, 2-time split application (T3R4) and Multicote, while the 1-time (T1R4) had the lowest hay yield. At the second cutting, the order of the hay yield was 5-time>Haifa, 2-time (T3R4) > SuperU > 1-time (T1R4). The differences of the hay production may be associated with the N use efficiency. Multiple application could provide timely N to meet the plant growth, while the single application might have the great potential of N lost as nitrate leaching or ammonia emission. The controlled-release fertilizers could release N gradually, so the loss was relatively limited. On the other hand, they might not be able to meet the requirement of the plant growth sometimes.

Mint oil productions from both cuttings were higher with Multicote, T3R4 and SuperU. The lowest yield was under 5-time at the first cutting and under T1R4 at the second cutting. The total oil yield after combining two cutting was in an order of Multicote > 2-time (T3R4) > SuperU > 5-time > 1-time (T1R4). Our data indicate that controlled-release fertilizer and 2-time split application are the favorable treatments towards oil production. It is interesting that the high hay production was not able to convert to higher oil yield (e.g., 5-time).

Results from Small Plot Observations: Figure 8 compares data from the small plots with selected treatments from the main plots, such as T1R4 or T3R4, all receiving an N rate of 100 lb/a. Generally, both hay production and oil yield were higher from the first cutting than the second cutting. In the first cutting, the 5-time split N application had the highest hay yield, followed by SuperU, 2-time split application (T3R4) and Multicote, while the 1-time (T1R4) had the lowest hay yield. In the second cutting, the order of hay yield was 5-time > Multicote, 2-time (T3R4) > SuperU > 1-time (T1R4). Differences in

Figure 6. Soil pH under the different N fertilization methods (T1- all N in the spring and none after the first cutting; T3-2/3 of N in the spring and 1/3 after the first cutting) and rate (R1- R6, 250-0 lb/a).



hay production may be associated with N use efficiency, with multiple applications providing timely nitrogen to meet plant growth, while single applications might lead to greater potential N loss.

Mint oil production from both cuttings were higher with Multicote, T3R4 and SuperU. The lowest yield was under 5-time at the first cutting and under T1R4 at the second cutting. The total oil yield after combining two cuttings followed the order of Multicote > 2-time (T3R4) > SuperU > 5-time > 1-time (T1R4). The data suggest that controlled-release fertilizer and 2-time split application are favorable treatments for oil production. Interestingly, high hay production did not necessarily convert to higher oil yield (e.g., 5-time).

Figure 7. SPAD leaf greenness under the different N fertilization treatment (T1- all N in the spring and none after the first cutting; T3-2/3 of N in the spring and 1/3 after the first cutting) and rate (R1- R6, 250-0 lb/a).

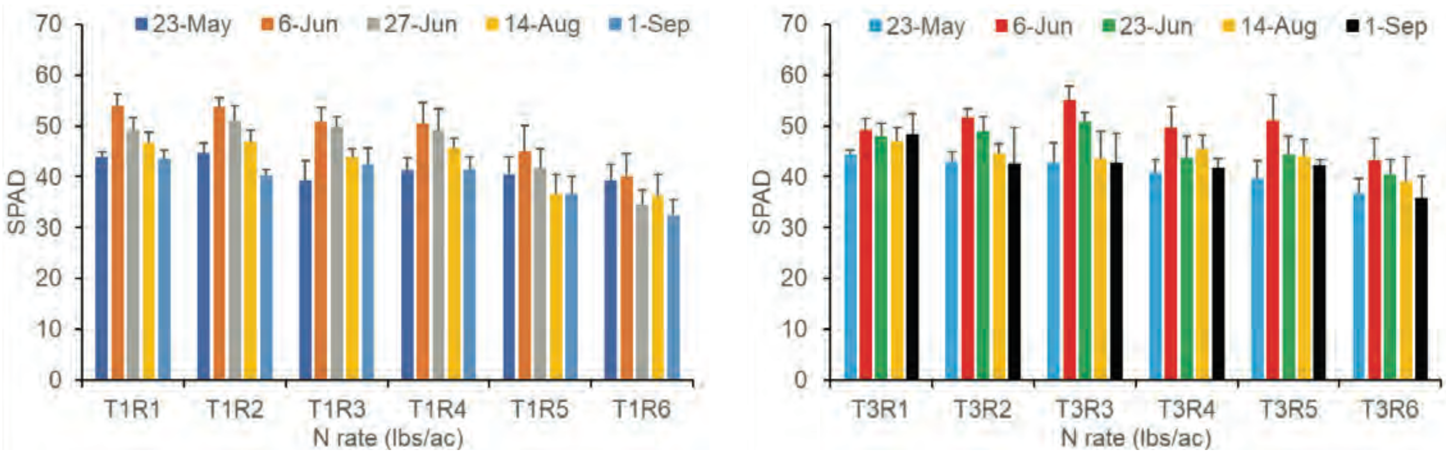
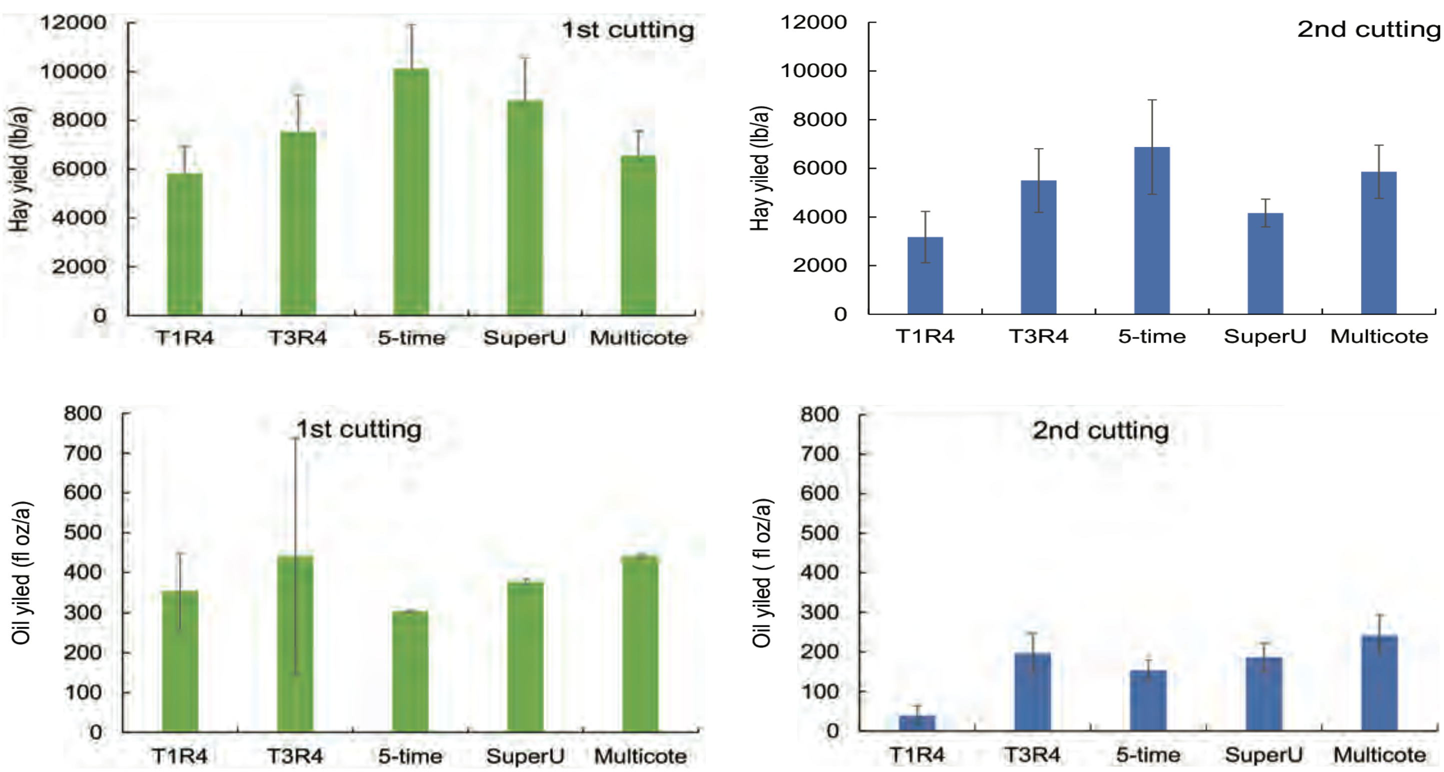


Figure 8. Hay production and mint oil production under the different N fertilizer methods (T1R4 - all N in the spring; T3R4 -two third of the N applied in spring and one third applied in fall; 5-time-the N was split-applied throughout the season and each time has the amount of 1/5; Multicote and SuperU were two controlled-release fertilizers. The N rate was 100 lb/a).



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News from O.E.O.G.L.

Scott Setniker, O.E.O.G.L. Chairman, Independence, Oregon

Plans are beginning for the 2025 Annual Convention. Be sure to mark your calendars. The dates will be January 9 & 10 at the Salishan Resort, Gleneden Beach, Oregon.

If you are interested in advertising in the 2025 Meeting Program and Directory, a mailing will be made in August. If you do not receive the mailing or would like additional information on advertising, contact Shawn or Jenny at the Association office at (503) 364-2944.

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