FINAL REPORT

Washington State Grape and Wine Research Program

DUE 5:00 p.m. December 12th, 2016
by email to: ARCGrants@wsu.edu

Wine Research Advisory Committee Research Review – January 18-19, 2017

PROJECT TITLE: Impact and Management of Plant-Parasitic Nematodes in Washington Wine Grape Vineyards

Project Duration: FY15, FY16, and FY17 (July 2014-Jun 2017 – 1 yr no-cost extension until Jun 2018)

WRAC Project No.:

PI Name:	**Michelle M. Moyer**
Organization	Washington State University – IAREC
Address	24106 N. Bunn Rd, Prosser, WA 99350
Telephone	509-786-9234
Email	michelle.moyer@wsu.edu

CO-PI Name:	**Inga Zasada**	**CO-PI Name:**	**R. Paul Schreiner**
Organization	USDA-ARS	Organization	USDA-ARS
Address	3420 NW Orchard Ave., Corvallis, OR 97330	Address	3420 NW Orchard Ave., Corvallis, OR 97330
Telephone	541-738-4051	Telephone	541-738-4095
Email	inga.zasada@ars.usda.gov	Email	paul.schriener@ars.usda.gov

Cooperator Name:	**Julie Tarara, Mimi Nye, Kari Smanse, Joe Cotta**	**Cooperator Name:**	**Richard Hoff**
Organization	Ste Michelle Wine Estates	Organization	Mercer Canyon
Description of participation:	Contacts for where the research trials relating to degree day modeling, rootstock evaluations, and nematicide trials are held.	Description of participation:	Contact for where research trials relating to degree day modeling and nematicide trials are held.
Cooperator Name:	**Rick Hamman**		
Organization	Hogue Ranches / Mercer Estates Winery		
Description of participation:	Contact for where research trials relating to degree day modeling are held.		

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BUDGET AND OTHER FUNDING SOURCES

FINAL FINANCIAL REPORTING

BUDGET: 3316-5633

	Year 1 (FY15)	**Year 2 (FY16)**	**Year 3 (FY17)**
	Jul 14 – Jun 15	Jul 15 – Jun 16	Jul 16-Jun 17
Item			
Salaries[1]	$13,381	$19,273	$19,073
Benefits[1]	$13,543	$15,571	$15,506
Wages[2]	$6,500	$6,500	$6,760
Benefits[2]	$137	$637	$676
Supplies[3]	$6,761	$750	$1,550
Travel[4]	$2,243	$2,243	$1,964
Total	$42,565	$44,974	$45,529

Footnotes:

[*]Specific funding expenses for FY15 and FY16 are presented in the previous proposals. FY17 is presented here for informational purposes only.

[1] Academic-year M.S. Graduate student (Katherine East) = $14,333 + $13,932 (stipend + benefits). Funding for technician (Jensena Newhouse) for 15% of her time = $4,740 + $1,574 (salary + benefits).

[2] Summer employment of Katherine East: $26/hr *x* 20 hrs/week ($13.00/hr full-time equiv) *x* 13 wks = $6760 + Benefits (10%; $676).

[3]Soil Sampling supplies (bags, labels): $200. Microscopy: Microscopes slides and coverslips: $150. Leaf nutritional analysis = $1,000. Nematode Extraction: Supplies for elutriation = $200.

[4]Research site travel (GDD Model and OR): 2000 miles/year x $0.56/mile = $1,120. Attendance of Katherine East at 2017 ASEV Meeting (estimated location, Portland, OR). Registration ($60), hotel ($140/night *x* 4 nights=$560), travel (400 miles RT @ $0.56 = $224) = $844.

Total Project Funding: **$133,068**

Project Budget Status: The project termed in June 2017, fully expensed.

OTHER FUNDING SOURCES/SUPPORT

Agency Name: **Chemical Companies**
Notes: All nematicide products have been donated by their respective companies. In addition, travel to nematicide trial sites is being covered by company donations. Total donations near $12,000.

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Project Summary:

- Very little is known about the impact of plant-parasitic nematodes on grapevines in Washington. Considering that Washington State is the second largest wine grape producer in the U.S. with a $154 million wine industry in 2009 (USDA, 2010), and knowing that plant-parasitic nematodes are important pests in other grape-producing regions, this is an area of concern for the industry. Washington grape growers lack the basic information regarding plant-parasitic nematodes required to make informed pre- and post-plant management decisions. This void in knowledge comes at a time when growers are interested in being part of sustainable production programs and when pre-plant soil fumigation is becoming more regulated.
- All studies occurred in commercial vineyards. 1) A rootstock trial was planted in a site that had both fumigated and non-fumigated sections, so we can monitor how effective both fumigation and rootstocks are at keeping nematode population densities low. 2) Other commercial sites with known nematode populations were routinely sampled throughout the year to determine when the infective stage (second-stage juvenile; J2) of Northern Root-knot Nematode (*Meloidogyne hapla*) was present. A similar model for *Meloidygne chitwoodi* exists for potatoes in Washington (Pinkerton et al. 1991). The threshold temperature for development of *M. hapla* is 10° C (Tyler 1933), indicating that a typical degree-day calculation with a 10° C base could be used to determine nematode generation time. Root growth data was also collected at these sites to determine if the timing of root flushes in grapevine influence nematode population development. 3) Finally, sites with known nematode populations were also included in a post-planting nematicide evaluation trial, to determine the effectiveness of different, new products that are making their way to the market. Effectiveness is determined by a reduction in nematode numbers or an increase in yield or vine vigor.
- From a management perspective, knowing when J2 will be abundant in soil will be key since this is the life stage that is the easiest to target with nematicides or other potential control options. The developmental model that we will create will provide information as to when this life stage occurs, and thus, when post-plant nematicide applications may be most effective. We have designed a suite of experiments to evaluate the post-plant nematicides/insecticides and to monitor *M. hapla* development in grapevines. This information is essential in order to make appropriate recommendations and ensure that growers are getting the most for their money.

Project Major Accomplishments:

We have designed a suite of experiments to evaluate post-plant nematicides/insecticides and to monitor *M. hapla* development in grapevines. This information is essential to making appropriate recommendations and ensure that growers are getting the most for their money.

Project Objectives:

1. Determine the impact of plant-parasitic nematodes on the establishment and productivity of Chardonnay on different rootstocks (FY17). This replaced an original objective relating to a vineyard that was established in 2013. A significant portion of the vineyard was lost to J-rooting of the cuttings during the 2013-2014 dormant season. After replanting lost vines in 2014, there was another significant loss of vines in the 2014-2015 dormant season

due to rodent damage. A vineyard assessment was made in Spring 2015, and we determined that entire varieties as well as entire replicates of some varieties had been lost, and the specific objective was not worth continuing at that site.

2. Create a life-cycle degree day model for *Meloidogyne hapla* (Northern root-knot nematode) on grapevines (FY15-FY17).
3. Evaluate the effectiveness of post-plant nematicides under Washington vineyard conditions (FY16-17). This replaced an irrigation objective that was originally proposed for FY15. The irrigation objective was eliminated after survey work determined that current industry-standard emitter spacing would not be sufficient to complete the outlined objectives.

Significant Results:

. When the term "more" or "less" is used below, it refers to being statistically different at P < 0.05. Dunnett's Method was used when comparing treatments to a control; Tukey's HSD was used when comparing across all treatments.

Objective 1 (Rootstock Trial): The length of the fumigation effect depended upon the target nematode. In this trial, dagger nematode was effectively managed by fumigation with metam sodium; few dagger nematodes were found in fumigated soil 2 years after fumigation compared to non-fumigated soil. Root-knot nematode was more difficult to manage long-term with soil fumigation. One year after fumigation (0.5 years after planting), root-knot nematode population densities were lower in fumigated soil compared to non-fumigated soil. However, by the following spring and onward, population densities of root-knot nematode were statistically similar between the two treatments. Consistent with our past greenhouse studies, rootstocks are poor hosts for root-knot nematode relative to own-rooted *Vitis vinifera*, seen in both our 2015 data (*see previous report*), and our 2016 data (**Fig. 1**).

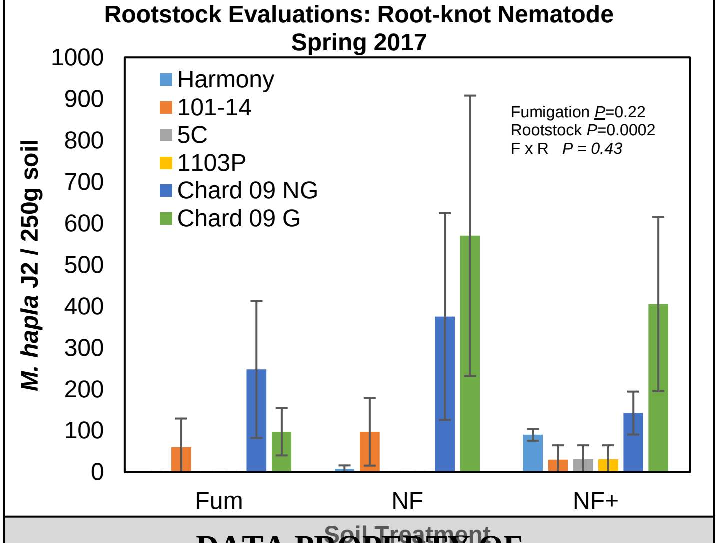

Fig. 1 Rootstocks were poor hosts for root-knot nematode, relative to own-rooted vines, but that effect began to dissipate as nematode pressure increased. Site treatments included a non-fumigated control, fumigation, and a non-fumigated area with the addition of nematodes (non-fumigated +).

There did not appear to be a nematode effect on dormant pruning weights after the first year (2015-2016 dormant season); more of an effect of grafting type. By the 2016-2017, a significant rootstock effect began to emerge. Harmony had the most pruning weights than all other rootstocks. This was followed by 1103P, 101-14, and non-grafted own-rooted. Grafted, own-rooted was not different from the non-grafted own-rooted, but did have significantly lighter pruning weights than 1103 P. Teleki 5C had the lowest dormant pruning weights, but it was not significantly less than the two own-rooted treatments.

Objective 2 (Development Model): Sampling for this objective will be completed in March 2017, with model development and validation completed by June 2017. The patterns of J2 present in soil and eggs in roots closely mirror each other in 2015 and 2016, when those patterns are compared to accumulated heat units in soil. *Meloidogyne hapla* has a single generation per year, with J2 density peaking over the winter (4291-4881 GDD_{soil}), then declining to a low density in late June to early July (1895-2379 GDD_{soil}). Egg density peaked in late July to August (2871-3069 GDD_{soil}). Similar to the egg peak, fine root tip density peaked at 2379-2871 GDD_{soil}. This data suggests that current recommendations for nematicide timing (spring) may not be fully aligned with nematode biology, as the product recommendation timing tend to focus on either early spring, when the timing to hit available J2 in the soil is in flux, or in mid-summer when there are little J2 present. Specific recommendations will be forthcoming after appropriate experiments can be conducted for confirmation on timing and efficacy (*a future project)*.

Objective 3 (Nematicide Trial): Product evaluated are listed below in Table 1. Our first nematicide trial began in 2015 at a site in the Horse Heaven Hills. The trial continued at that site in 2016 and evaluated 5 post-plant nematicide products. For the Horse Heaven Hills site, there were no differences in dormant pruning weights between treatments (2015), which was expected due to the general lack of response one would see as a result of first-year treatment. In 2016, there were no differences between treatments in terms of average vine yield, pruning weights, average cluster weight, Brix, and pH. However, for titratable acidity, there was a treatment difference, where the Movento + Velum Prime (fluopyram) treatment had significantly lower titratable acidity than the Velum Prime only treatment. By Fall 2016, there was no significant differences between treatment effects in terms of nematode numbers, and that was also seen in Spring 2017.

A second site in the Mattawa area was added in 2016 as well, evaluating 3 of the 5 products used in the Horse Heaven Hills trial. For the site in Mattawa, there were no yield differences (vine, cluster weights) between treated and untreated vines. There were no significant differences between the treatments and the control, except for Nimitz, which had lower pruning weights. This lack of vine response is expected since it is the first year of the trial at this site. Fruit quality data was not taken to reduce costs. By October 2016, only Salibro had significantly fewer nematodes than the untreated control and by spring 2017, all treatment different were lost.

Table 1 – Product rates, timing, and application type.

Product	Location	Rates	Timing	Application Type
Nimitz	Horse Heaven Hills, Mattawa	3.00 ai/acre	Apr	Drip
Salibro	Horse Heaven Hills, Mattawa	61.4, 30.7, 30.7 fl oz /acre	Apr, May, Jun	Drip
Velum Prime	Horse Heaven Hills, Mattawa	6.84 fl oz/ acre	Apr, Oct	Drip
Movento	Horse Heaven Hils	6.25 fl oz product / acre	May, Jun	Foliar

Velum Prime + Movento	Horse Heaven Hils	6.84 fl oz/ acre + 6.25 fl oz product / acre	Apr, Oct+ May, Jun	Drip + Foliar
Control	Horse Heaven Hills, Mattawa	n/a		Drip

Key Outcomes:

Objective 1: Our study found that fumigation reduced nematode populations for only about 1 year post-application. Thus, in heavily infested vineyards undergoing replant, additional measures combined with fumigation may be needed to ensure new vineyard longevity. Nematode-resistant rootstocks significantly reduced nematode numbers on vines in non-fumigated situations early in vineyard establishment, as expected based on results elsewhere. However, this rootstock effected appeared to lose strength over time. This trial will continue until approximately 2025 to monitor the long-term impacts of nematodes on vineyard establishment and productivity. While the use of rootstocks in vineyards is still not common in WA, they may become necessary as more vineyards undergo replant, to avoid production losses due to nematode infestations.

Objective 2: We have made several interesting observations related to root-knot nematode development in Washington. First, this nematode can overwinter in the J2 stage, which differs from previous observations in both grape and other systems. This nematode appears to peak in population from Fall through Spring, with a general drop in J2 numbers in mid-summer, which corresponds to an increase in eggs / females. There are very few J2 present during the beginning of the growing season in the spring and in early summer, which is when many nematicide products are currently being applied. This preliminary data suggests that current recommended nematicide timing may not be completely in line with nematode biology. However, additional studies are needed to provide more specific recommendations on timing adjustment.

Objective 3: Based on the data from Objective 2, one reason why we might be seeing less-than-desirable impacts of nematicides on nematode populations could be due to the currently-recommended timing of application. Most of the products evaluated focused their application timing in the late spring to early summer, during a time when J2, which are the most vulnerable stage of the nematode lifecycle, are not as abundant in soil. Since most products have specific environmental and plant requirements (i.e., temperature thresholds or the requirement of canopy development) that would preclude them from a late winter to early spring application (the 1st flush of J2), they may perform better with mid-season application. This suggestion is being made to manufacturers for consideration based on the data generated from this project.

***Industry Value and Benefit*:**

Overall, this research project is providing more biologically-relevant recommendations for nematode management and intervention. We are now seeing that our current-recommended best practices for pre-planting preparation may not be as effective as currently thought, and that recommendations for post-plant intervention may not be optimally aligned with nematode biology. Combined, this new information should help guide growers to better time nematicide applications, and potentially consider the use of rootstocks in vineyards heavily infested with root-knot nematode.

<u>Information Dissemination, Extension, and Outreach Activities:</u> *Select activities are highlighted below due to space limitations. Complete list available upon request.*

Presentations:

"Worms and Weather." 6 Jun 2017. Ste. Michelle Wine Estates Regional Winemakers Meeting. Prosser, WA, USA. ***Invited Presentation.***

"Managing Nematodes in a Maturing Wine Grape Industry." 19 Apr 2017. Washington Advancements in Viticulture and Enology (WAVE). Washington State Wine Commission, Prosser, WA, USA. ***Invited Presentation.***

Zasada, I. 20 Oct 2016. Root-knot nematode prefers Chardonnay: Insights into nematode management and biology in semi-arid wine grapes. OWRI Seminar. Corvallis, OR, USA.

Posters:

East, K., I. Zasada, P. Schreiner, and **M.M. Moyer**. 7 Feb 2017. "Developing Strategies for Root-knot Nematode Management in Washington Grapes." Poster. Washington Association of Wine Grape Growers Annual Meeting. Kennewick, WA, USA

Boren, A.N., J. Tarara, and **M.M. Moyer.** 7 Feb 2017 "Virus and Nematode Management in Grapevine for Replant Preparation." Poster. Washington Association of Wine Grape Growers Annual Meeting. Kennewick, WA, USA. *1st Place Undergraduate Poster*.

Moyer, M.M., I. Zasada, K. East, and P. Schreiner. 9 Feb 2016. "Evaluation of Rootstocks for Nematode Management in Washington Vineyards." WAWGG Annual Meeting. Kennewick, WA, USA. *(Award: 1st Place Professional)*

East, K.[+], I. Zasada, and M. Moyer. 9 Feb 2016. "Root-Knot Nematode: Developing Integrated Management Tools for Washington State Grape Growers." WAWGG Annual Meeting. Kennewick, WA, USA. *(Award: 2nd Place Student)*

East, K.[+], A. Howland, I. Zasada, and M. Moyer. 2016. Rootstocks for Management of *Meloidogyne hapla* in Washington State Vineyards. 67th ASEV Annual Meeting. Monterey, CA, USA. Technical Abstracts: p. 85.

East, K.[+], I. Zasada, and M. Moyer. 12 Nov 2015. "Root-Knot Nematode: Developing Integrated Management Tools for Washington State Grape Growers." WSGS Annual Meeting. Grandview, WA, USA.

Workshops:

"Nematode Management" in "Vineyard Scouting Workshop." Presented by I. Zasada. Organizers: Oregon Wine Research Institute. 4 May 2016. Milton-Freewater, OR, USA. ** Joint OSU, WSU and USDA Workshop (52 participants; 4 pesticide credits)

Tarara, J. and **M.M. Moyer**. 25 Jan 2017. "Washington Winegrape Replant Workshop." Prosser, WA, USA (50 participants)

Extension Publications:

Hoheisel, G.A., and M.M. Moyer (eds). Updated Annually. Pest Management Guide for Grapes in Washington. WSU Extension #EB0762. Pullman, WA, USA. 68 pp. (Zasada is the author of the nematode section).

Moyer, M.M., and S. O'Neal. (eds). 2014. *Pest Management Strategic Plan for Washington State Wine Grapes*. Western IPM Center-United States Department of Agriculture. http://www.ipmcenters.org/pmsp/pdf/WA_WineGrape_PMSP_2014.pdf. 76 pp.

Journal Publications:

Zasada, I.A., A. Howland, A. Peetz, K. East, and M. Moyer. **(2019).** *Vitis* spp. Rootstocks are Poor Hosts for *Meloidogyne hapla,* a Nematode Commonly Found in Washington Wine Grape Vineyards. Am. J. Enol. Vit. *Accepted – In press.*

East, K.E., M.M. Moyer, I.A. Zasada, and R.P. Schreiner. Developmental Dynamics of *Meloidogyne hapla* in Washington Wine Grapes. Plant Dis. – *In Review – Submitted 2018.*

Literature Cited:

U.S. Department of Agriculture. 2010. Grape Release. http://www.wawgg.org/files/documents/2010_Ag_Stats_Grape_Report_for_2009_crop_year_REVISED_FINAL_(2).pdf

Pinkerton, J.N., Santo, G.S., and Mojtahedi, H. 1991. Population dynamics of *Meloidogyne chitwoodi* on russet Burbank potatoes in relation to degree-day accumulation. Journal of Nematology 23:283-290.

Tyler, J. 1933. Development of the root-knot nematode as affected by temperature. Hilgardia 7:392-415.