FINAL REPORT

Washington State Grape and Wine Research Program

PROJECT TITLE: Epidemiology and Management of Grapevine Leafroll and Redleaf Diseases in Washington Vineyards

Project Duration: ***July 1, 2014 to June 30, 2017***
WRAC Project No.: 10A-3361-1616

Principal Investigator: **Naidu A. Rayapati**

Associate Professor (Virology), Department of Plant Pathology, Washington State University Prosser, WA 99350. E-mail: naidu.rayapati@wsu.edu; Phone: 509-786-9215.
Role: Overall coordination of the project, conduct proposed research, carryout related extension and outreach activities, offer experiential educational opportunities for undergraduate students in V&E program, budget and personnel management, submit semi-annual and annual reports.

Collaborators:

i. Dr. Doug Walsh, Professor, Entomology, WSU-IAREC.
Role: Collaborative research on vectors of grapevine leafroll disease.
ii. Dr. Neil McRoberts, UC-Davis, CA.
Role: Collaborative research on epidemiology of grapevine leafroll disease.
iii. Drs. William Dawson and Siddarame Gowda, University of Florida, Lake Alfred, FL.
Role: Collaborative strategic research on grapevine leafroll-associated viruses.

Cooperators:

i. Growers, nurseries, industry stakeholders and regulatory agencies. *Role: Provide access to vineyards for sample collections, field data collection, extension and outreach activities.*

BUDGET AND OTHER FUNDING SOURCES

FINAL FINANCIAL REPORTING
BUDGET *(LIST COMPLETED BUDGET NUMBERS)*

	Year 1 FY	**Year 2 FY**	**Year 3 FY**
	Jul 14 – Jun 15	Jul 15 – Jun 16	Jul 16 - Jun 17
Item			
Salaries	63,435	59,037	62,691
Benefits	31,280	29,081	32,700
Wages	11,040	16,653	11,133
Benefits	725	0	1,113
Equipment	0	0	0
Supplies	18,108	19,229	19,808
Travel	3,000	4,000	4,000
Miscellaneous	0	0	0
Total	127,588	128,000	131,445
Total Project Funding: $387,033			

Project Budget Status:
A balance of $118,563.12 is remaining as of November 27, 2016. This is largely due to delayed allocations and internal transfers. However, these funds are encumbered and will be expended for lab supplies and reagents to conduct project activities and to support salary for project personnel until June 30, 2017. In addition, funds will be used by Rayapati's team for conference registration and travel expenses to attend the 2017 WAWGG annual meeting, February 7-9, 2017, Kennewick, WA; registration and travel to attend the 68th ASEV National Conference, June 26-29, 2017, Bellevue, WA and the American Phytopathological Society annual meeting, August 5-9, 2017, San Antonio, TX.

OTHER FUNDING SOURCES/SUPPORT
(*Please include all other funding sources that have been awarded and/or anticipated.)*

During July 2014 and June 2017, funding was obtained from the following resources to conduct research on virus diseases of grapevines. It should be noted that these projects involve multiple institutions and some activities of these projects are distinct and others complement activities of the project funded by the WSGWRP. Collectively, the research-based information generated from these projects is advancing our understanding of virus diseases benefiting grape growers and nursery certification and improvement programs in Washington State.

1. Washington State Commission on Pesticide Registration:
   Jan-Dec 2014: $22,920, Jan-Dec 2015: $23,062, Jan-Dec 2017: $23,000.
2. Northwest Center for Small Fruits Research:
   Oct 2014-Sept 2015: $33,471; Oct 2015-Sept 2016: $33,471; Oct 2016-Oct 2017:$33,406.
3. WSDA Nursery Surcharge:
   Jul 2014-Jun 2015:$20,470; Jul 2015-Jun 2016: $23,470
4. WSDA-Specialty Crop Block Grant Program:
   i. September 30, 2014 to April 2017: $153,080.00
   ii. September 30, 2015 to April 30, 2018: $247,878
   iii. September 30, 2016 to September 29, 2019: $248,587

In addition, two undergraduate research internships from WSU-CAHNRS and V&E Program, one from NSF-REU program funds awarded to Heritage University, one PhD assistantship for three years from USAID-Indonesia supported students worked in the project.

Other support is for informational purposes only, for Washington State Grape & Wine Research Program to understand the scope of the project. These estimated costs are not presented as formal cost-sharing and therefore do not constitute a cost-share obligations on the part of Washington State University. Moreover, there is no requirement for WSU to document this other support of project as part of any cost-share or matching obligation.

FINAL REPORT

Project Summary:

Viral diseases are recognized as one of the most serious impediments to the sustainability of Washington's grape and wine industry. Due to the lack of curative measures, science-based knowledge is necessary for deploying alternative strategies to mitigate negative impacts of viral diseases. Towards this goal, a mix of fundamental and translational research was conducted to better understand viral diseases affecting Washington vineyards. Collaborative avenues and participatory approaches were pursued in partnership with grape growers to conduct these activities. Significant achievements of this project were highlighted in an article published in Good Fruit Grower August 5, 2016 (http://www.goodfruit.com/hansen-certified-plants-are-only-the-first-step/). The research-based knowledge was disseminated to various stakeholders by a variety of dissemination pathways. Research presented in this report was funded, in part, by the WSU Agricultural Research Center, the Wine Research Advisory Committee, the Washington Wine Commission, the Washington State Grape and Wine Research Program, WSDA Specialty Crop Block Grant Program, WSDA Grapevine Certification and Nursery Improvement Program, Washington State Commission on Pesticide Registration, Northwest Center for Small Fruits Research, and Altria - Chateau Ste. Michelle Wine Estates.

Vineyard surveys have indicated that grapevine leafroll disease continues to be a major problem, whereas red blotch and fanleaf degeneration and decline diseases are emerging concerns to Washington's grape and wine industry. Virus indexing of grapevine samples have revealed that *Grapevine leafroll-associated virus 3* (GLRaV-3) continues to be the most widespread among the viruses documented in many appellations. Leafroll and red blotch diseases produce similar, though not identical, symptoms in many red grape cultivars, whereas white grape cultivars showed no apparent symptoms of leafroll and red blotch diseases. Therefore, virus-specific diagnostic assays must be used for reliable detection of viruses associated with these two disparate diseases. Two nematode-transmitted viruses (*Grapevine fanleaf virus* and *Tobacco ring spot virus* [TRSV]) were detected in some wine grape cultivars showing fanleaf degeneration and decline symptoms. Using baiting assays, the spread of TRSV was demonstrated from symptomatic grapevines to healthy cucumbers and Cabernet franc vines by soil-inhabiting nematodes. Using morphological characteristics and genome sequence analyses, the dagger nematode *Xiphinema rivesi* was identified as a possible vector of TRSV.

Studies in commercial vineyards have shown that leafroll, red blotch, and fanleaf degeneration and decline can cause significant reduction in fruit yield and quality, especially sugars considered as the hallmark of wine grape quality. However, these negative impacts were found to be cultivar- and site-specific responses and likely influenced by genotype-by-environment interactions. Multi-season studies in commercial vineyards have shown continued spread of leafroll (predominantly GLRaV-3) into newly planted 'clean' vineyard blocks from external sources of infection. The spatial and temporal distribution of symptomatic vines in young plantings indicated that spread of leafroll during the initial years of post-planting likely occurs from heavily infected neighboring old blocks. In subsequent years, aggregation or clustering of symptomatic vines within young blocks was observed, suggesting secondary spread of leafroll between neighboring vines. Roguing of infected vines showed encouraging results to reduce viral incidence in new plantings. Outputs of the project are advancing sustainable disease management strategies in vineyards and strengthening the grapevine supply chain to prevent viral spread through planting stock.

Project Major Accomplishments:

I. Current status of grapevine viruses in Washington vineyards.

Grapevine is a treasure trove for a wide range of viruses with distinct biochemical and epidemiological properties. During this project period, surveys were continued to document viruses present in Washington vineyards. Leaf samples from vines showing typical symptoms of leafroll, red blotch, and fanleaf degeneration and decline and those suspected for viral symptoms were collected from red grape varieties. Leaf samples from white grape varieties were collected randomly, since they do not show apparent symptoms. Samples were processed and tested using molecular diagnostic assays established in Rayapati's lab. Whereever necessary, cloning and sequence analyses of viral genome fragments were carried out for additional confirmation. In addition, high-throughput sequencing was used as needed to determine the viral status of grapevines. Viruses documented so far in Washington vineyards are listed in Table 1. Vineyard surveys should be continued to contain emerging viral diseases and ensure 'alien' viruses are not introduced into the State.

Table 1. A list of viruses documented in Washington vineyards

Disease/Disorder	Virus(es)
Grapevine leafroll complex	Grapevine leafroll-associated virus 1 (GLRaV-1), GLRaV-2, GLRaV-3, and GLRaV-4 & its strains GLRaV-5, GLRaV-9.
Rugose Wood Complex	Grapevine Rupestris stem pitting-associated virus (GRSPaV), Grapevine virus A (GVA), GVB, GVE
Red blotch	Grapevine red blotch-associated virus (GRBaV)
Fanleaf	Grapevine fanleaf virus (GFLV) & Tobacco ring spot virus (TRSV)
Syrah decline	Grapevine Syrah virus -1
Fleck	Grapevine fleck virus

Vineyard surveys have underscored practical difficulties in identification of viral diseases based exclusively on visual symptoms. Therefore, virus-specific diagnostic assays must be used for reliable detection of viruses associated with specific disease symptoms. The overall results have indicated that grapevine leafroll disease continues to be the most widespread and economically important viral disease to Washington's grape and wine industry. Red blotch and fanleaf degeneration and decline diseases are emerging as significant concerns to the industry. Among the viruses listed in Table 1, *Grapevine leafroll-associated virus 3* (GLRaV-3) is by far the most widespread in Washington vineyards.

II. Relative distribution of grapevine leafroll and red blotch diseases in Washington vineyards.

Vineyard surveys in five appellations were conducted during 2014 through 2016 seasons to assess the relative distribution of grapevine leafroll and red blotch diseases. In the case of red-berried cultivars, leaf samples were collected from individual grapevines exhibiting typical symptoms of leafroll or red blotch as well as from grapevines suspected for these diseases. In white grape cultivars, however, leaf samples from individual grapevines were collected randomly due to the absence of visual symptoms. Samples were extracted and tested for GLRaV-3 by reverse transcription (RT)-PCR and by PCR for the presence of GRBaV. Names of commercial vineyards and appellations are withheld due to confidentiality. Of the 2,141 samples tested, nearly 66.83% were positive for GLRaV-3 and about 6% positive for GRBaV (Fig. 1).

Interestingly, about 8.73% were positive for both viruses suggesting that GLRaV-3 and GRBaV can occur as mixed infections. About 18.4% were negative for both viruses. Some of these samples negative for GLRaV-3 and GRBaV were tested positive for other leafroll viruses, such as GLRaV-1, -2, and -4. Overall, the survey results indicated that GLRaV-3 is the most predominant and wide spread, relative to GRBaV, in Washington vineyards. The survey also revealed that symptoms of leafroll and red blotch appear around *véraison* and are highly similar, though not identical, in many red grape cultivars. Similar to leafroll, white grape cultivars showed no apparent symptoms of red blotch. Consequently, symptoms of leafroll and red blotch can easily be confused in vineyards and virus-specific diagnostic assays are necessary for reliable diagnosis of these two disparate virus diseases under field conditions. A multiplex PCR assay was optimized for the detection of GLRaV-3 and GRBaV in single and/or co-infections. Further validation of the multiplex PCR assay is in progress to make it as a cheaper, faster, and reliable assay for indexing large volume of grapevine samples benefiting nurseries and growers.

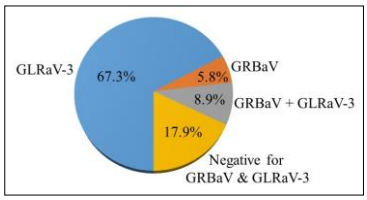

Fig. 1. Presence of Grapevine leafroll-associated virus 3 (GLRaV-3) and Grapevine red blotch-associated virus (GRBaV) in samples showing leafroll and red blotch symptoms or suspected for infection with leafroll or red blotch diseases. A total of 2141 samples were tested by PCR for these two viruses.

III. Studies on soil-borne viral diseases in Washington vineyards.

Using traditional and next-generation sequencing approaches, TRSV and GFLV were documented in five wine grape cultivars showing fanleaf degeneration and decline symptoms. Since these cultivars were planted in three geographically separate vineyard blocks, it is likely that GFLV and TRSV are emerging as significant problems to vineyard health. Since TRSV is known to be spread by dagger nematodes and the dagger nematode vector for GFLV (*Xiphinema index*) is not reported in Washington State, further studies were conducted to examine the spread of TRSV. A baiting assay was used to demonstrate that TRSV can be spread by soil-inhabiting nematodes from symptomatic grapevines to healthy cucumbers and Cabernet franc vines. Soil samples from vineyard blocks affected with TRSV were found to have spiral nematodes *(Helicotylenchus* sp.*),* lesion nematodes *(Pratylenchus* sp.*),* ring nematodes *(Criconemoides* sp.*)* and dagger nematodes *(Xiphinema* sp.). The detection of TRSV by RT-PCR in dagger nematodes, but not in other nematodes, suggested their potential as a vector of TRSV (Fig. 2).

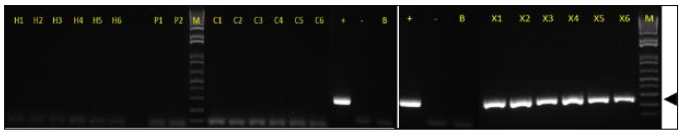

Fig. 2. Detection of TRSV in single nematodes. RT-PCR products were resolved by electrophoresis in 1.0% agarose gels and visualized under UV light after staining with Gel Red. Lanes H1-H6 = Spiral nematode, P1 & P2 = Lesion nematode, C1-C6 = Ring nematode and X1-X6 = Dagger nematode. Lanes '+', '-', and 'B' = positive, negative and buffer controls, respectively. Lane M = size of DNA molecular weight markers (in base pairs or bp) to estimate the size of DNA bands amplified in PCR. Arrow head on right indicates the size of a 254 bp DNA band amplified from dagger nematode samples (lane X1 to X6), but not from other nematode species.

Using morphological characteristics and genome sequence analyses, the dagger nematode was identified as *X. rivesi*. An analysis of soil samples from vineyard blocks affected with GFLV revealed the absence of dagger nematodes, including the dagger nematode *X. index*. Based on these results, it can be concluded that the spread of GFLV can be prevented by using virus-tested

planting stock, whereas prevention of TRSV spread should include a combination of nematode vector management and clean planting stock.

IV. Impact of viral diseases on fruit yield and quality attributes.

Impacts of grapevine leafroll and red blotch diseases on fruit yield and quality attributes (total soluble solids or sugars, juice pH, titratable acidity and berry anthocyanins in red varieties) were measured in red grape cultivars planted in commercial vineyards in three appellations. Based on the results obtained during this project period, it can be concluded that:

i. Both GLD and GRBD affects fruit yield and quality (especially sugars) in red grape cultivars examined during 2014, 2015 and 2016 seasons. In general, negative impacts of GRBD on sugars appears to be relatively higher than GLD.
ii. The negative impacts on fruit yield and total sugars were found to be variable between wine grape cultivars and between seasons, and in different geographic locations. This indicates cultivar- and site-specific responses to viral infections.
iii. Interestingly, impacts on grape juice pH and TA were not as pronounced as impacts on fruit yield and berry sugars.
iv. Mixed results were obtained with regard to berry skin anthocyanins depending on the disease and cultivar.
v. Impacts of TRSV on yield and fruit quality was determined in one red grape cultivar (Grenache) during 2015 and 2016 seasons. The data indicated that symptomatic vines produced significantly less yield due to reduced number of clusters and smaller size berries. The fruit soluble solids (or sugars, measured as °Brix) in berries harvested from symptomatic vines were significantly decreased compared to sugar levels in berries of non-symptomatic vines. Interestingly, no differences were observed in juice pH and TA and berry anthocyanins between symptomatic and non-symptomatic vines. It should be noted that both symptomatic and non-symptomatic vines tested positive for TRSV in RT-PCR assays suggesting that virus-infected vines can perform well as long as they don't express fanleaf degeneration and decline symptoms.

These studies should be continued to advance our understanding of site- and cultivar-specific responses to viral infections and make short-term adjustments and long-term adaptations to viticultural practices for mitigating negative impacts of viral infections in vineyards.

V. Spread of virus diseases.

Although planting new vineyards with virus-tested clean planting stock is recognized as the first line of defense against viral diseases, post-planting disease management strategies are critical for sustaining vineyard health and productivity. Towards this end, studies were conducted for multiple seasons on the spread of viral diseases into and within new plantings. Due to its economic significance, efforts were focused on the spread of leafroll disease in three vineyard blocks planted with 'clean' planting stock. These blocks were planted in different years with three wine grape cultivars (Cabernet Sauvignon, Syrah, Petite Sirah, Malbec) and in geographically separate locations in close proximity to old blocks heavily infected with leafroll. The results from Cabernet Sauvignon, Syrah and Petite Sirah blocks was presented in 2015 Project Annual Report. An example of spatial and temporal distribution of leafroll in a vineyard block planted with clean Malbec cuttings (Fig. 3) indicated higher number of symptomatic vines in each season compared to previous seasons, suggesting increased incidence of the disease with time in these young plantings.

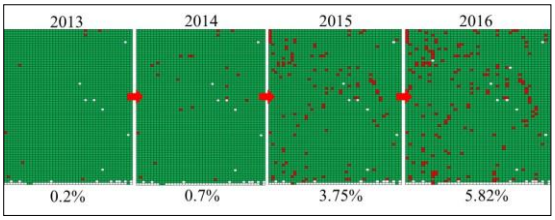

Fig. 3. *Spatial and temporal distribution of leafroll disease in a young block planted with clean Malbec cuttings during four seasons. Symptomatic vines (marked as red squares) were positive for GLRaV-3. Number of infected vines as percent of totalvines planted in the block is shown below each map.*

A brief account of this study was described in Good Fruit Grower August 5, 2016 (http://www.goodfruit.com/hansen-certified-plants-are-only-the-first-step/). A summary of our results obtained from Cabernet Sauvignon, Syrah and Petite Sirah blocks is presented below. The spatial distribution of symptomatic vines during initial years of disease spread indicated a disease gradient in which the highest percentage of vines showing symptoms occurred in rows close to the heavily infected blocks and the disease incidence declined with increasing distance from that block. This "edge effect" is an indication of disease spread occurring from infected vineyards proximal to the newly planted block. Aggregation or clustering of symptomatic vines observed in subsequent years indicates secondary spread of the disease between neighboring vines within young blocks. The secondary spread of GLD in young plantings could largely be due to vine-to-vine movement of vectors. The results provided strong evidence of leafroll spread from neighboring old blocks to young vineyards planted with virus-tested 'clean' planting stock. These studies should be continued for a better understanding of intrinsic and extrinsic factors contributing to the spread of leafroll in new plantings.

VI. Roguing as a disease management tactic in replanted vineyards

Many growers are planting new vineyards or replanting existing vineyards with cuttings bought from certified nurseries. Due to the short supply of certified planting stock, some growers are planting new vineyards with cuttings obtained from existing vineyards of unknown sanitary status. In both situations, our studies have indicated that cuttings may be carrying virus(es) and young vines can exhibit symptoms during the first few years after planting, giving false impression that new infections are due to root grafting or spread by insect vectors from residual roots. In order to clarify these practical issues raised by many growers and to implement roguing as a post-planting disease management strategy, we have monitored vineyard blocks replanted with red-fruited grape cultivars. In a 5.5-acre Cabernet Sauvignon block planted in 2015 with cuttings from another grower's vineyard, 11.82% vines showed leafroll symptoms and tested positive for GLRaV-3. By roguing and replanting with virus-tested clean cuttings, the grower was able to bring down the incidence to 1.04% in 2016 season (Fig. 4). In a Syrah bock planted in 2015 with cuttings of compromised sanitary status, 3.5% vines showed leafroll symptoms and tested positive for GLRaV-3. By roguing and replanting with virus-tested cuttings, the disease incidence in this block was brought down to 0.05% incidence in 2016 season. Roguing of symptomatic vines and replanting with virus-tested cuttings are being implemented to further reduce disease incidence in these two blocks.

In another location, we monitored four newly planted Syrah blocks. Two blocks (8.81 and 9.94 acres) heavily infected with leafroll were replanted in 2015 and another two infected blocks (4.24 and 5.51 acres) replanted in 2016. The Syrah cuttings planted in all four blocks were sourced from a commercial block with no history of viral infections. Three vines in one block planted in 2015 showed leafroll symptoms and tested positive for GLRaV-3. The symptomatic vines were removed and will be replanted with virus-tested cuttings. These observations suggest

that verifying the sanitary status of source vines prior to taking cuttings will significantly prevent the risk of virus introduction into new plantings via contaminated cuttings. The blocks will be monitored for the effectiveness of roguing in reducing GLD spread within new plantings. Similar studies are being conducted in other vineyard blocks planted with either certified or non-certified planting stock and the results will be presented in future reports.

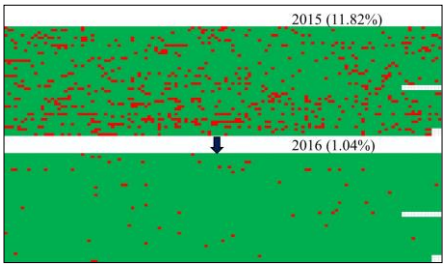

Fig 4. Spatial and temporal distribution of symptomatic vines in a Cabernet Sauvignon block (5.5 acres) planted in spring 2015 with a compromised planting stock. Roguing of symptomatic vines (tested positive for GLRaV-3) in fall 2015 and replanting with virus-tested cuttings in spring 2016 has reduced symptomatic vines from 11.82% to 1.04%.

VII. Information Dissemination, Extension, and Outreach Activities:

Collaborative avenues and participatory approaches were pursued in partnership with grape growers to conduct these activities. The research-based knowledge was disseminated to various stakeholders by a variety of dissemination pathways. A complete list publications, industry presentations, posters, and other educational and outreach activities are presented below:

Note: R.A. Naidu and **Naidu Rayapati** are the same person.

Peer-reviewed publications:

1. Poojari, S., Alabi, O.J., Okubar, P.A. and **Naidu, R.A**. 2016. SYBR® Green-based real-time quantitative reverse-transcription PCR for detection and discrimination of grapevine viruses. Journal of Virological Methods 235: 112–118.
2. Alabi, O.J., Casassa, L.F., Gutha, L.R., Larsen, R.C., Henick-Kling, T., Harbertson, J.F., and **Naidu, R.A**. 2016. Impacts of grapevine leafroll disease on fruit yield and grape and wine chemistry in a wine grape (*Vitis vinifera* L.) cultivar. PLoS ONE 11: e0149666.
3. Walker, L., Bagewadi, B., Schultz, A., and **Naidu, R.A**. 2015. First report of *Tobacco ringspot virus* associated with fanleaf disease in a Washington State vineyard. Plant Disease 99:1286.
4. **Naidu, R.A**., Maree, H.J., and Burger, J. 2015. Grapevine leafroll disease and associated viruses – A unique pathosystem. Annual Review of Phytopathology 53:613-634.
5. Jones, T.J., **Naidu, R.A**., and Nita, M. 2015. Occurrence of *Grapevine leafroll associated virus-2, −3* and *Grapevine fleck virus* in Virginia, U.S.A., and factors affecting virus infected vines. European Journal of Plant Pathology 142: 209-222.
6. **Naidu, R.A**., Rowhani, A., Fuchs, M., Golino, D., and Martelli, G.P. 2014. Grapevine leafroll: A complex viral disease affecting a high-value fruit crop. Plant Disease 98:1172-1185.
7. Alabi, O.J., Al Rwahnih, M., Mekuria, T., and **Naidu, R.A.** 2014. Genetic diversity of *Grapevine virus A* in Washington and California vineyards. Phytopathology 104:548-560.

Extension publications:

1. **Naidu, R.A**., 2016. Grapevine viruses and clean plants. In: Vine to Wine: Successfully Establishing a Vineyard and Winery. Moyer, M.M. and G.A. Hoheisel (eds). *WSU Extension Publication* OM41. Washington State University.

(https://www.youtube.com/watch?v=StCBEEWyBeo&index=9&list=PLajA3BBVyv1xbUDLr44fV4sW7ubL99aNO)

2. Hoheisel, G., Moyer, M.M., Daniels, C.H., Miller, T.W., Walsh, D., Zasada, I., **Naidu, R. A.**, and Davenport, J.R. 2015. Pest Management Guide for Grapes in Washington. EB0762, 68 pp.
3. Moyer, M., **Naidu, R.A**., and Steigmeyer, R. 2015. Field guide to clean plants & quarantines for grapes in Washington State (English & Spanish versions). 43 pp.
4. **Naidu, R.A.** 2014. Virus Diseases. In: 2015 Pest Management Guide for Grapes in Washington. WSU Extension Bulletin EB0762, pp.28-31.
5. **Naidu, R.A.**, Scharlau, V. 2014. Why 'clean' plants – Fact sheet (English & Spanish versions) (4 pages).

Industry trade journals:

1. **Naidu, R.A.** and Walsh, D. 2015. Is 'grape virus tax' hitting your pocketbook? Good Fruit Grower May 15, 2015. Vol. 66, No. 10, pages 10-11.

Industry Presentations (Oral):

1. **Naidu, R.A.** 2016. An overview of virus diseases in Washington vineyards. Washington State Grape Society annual meeting. November 10-11, 2016, Grandview, WA.
2. **Naidu, R.A.** 2016. It spread like…a virus: How leafroll spreads from old blocks to new plantings; What happens if I see something fishy and I want to test my vines? Industry Expansion Bottleneck: Where Will You Get Your Plants? October 27, 2016, The Clore Center, Prosser, WA. (Oral).
3. **Naidu, R.A.** 2016. Managing viruses in Washington vineyards. WAVE 2016 Washington Advancements in Viticulture and Enology. WSU's Ste. Michelle Wine Estates Wine Science Center, Richland, WA. July 14, 2016.
4. **Naidu, R.A.** 2016. Rational Mealybug Control Programs vs. Irrational Exuberant Programs. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
5. **Naidu, R.A.** 2015. Update on grapevine virus diseases. Ste. Michelle Wine Estates Vineyard Management Training 2015. April 2, 2015. Paterson, WA
6. **Naidu, R.A.** 2014. Finding virus infected plants, symptoms, sampling, storing and testing. WAWGG Summer Tour "How Clean Plants are Made", August 7, 2014, Prosser, WA.
7. **Naidu, R.A.** 2014. How to inspect a nursery and look for infected grape plants? WSDA-Plants Services Program Staff Meeting. June 17, 2014, Prosser, WA.
8. **Naidu, R.A.** 2014. Red blotch and leafroll update. Ste. Michelle Wine Estates. May 28, 2014, Prosser, WA.
9. **Naidu, R.A.** 2014. Grapevine Red blotch disease. G.S. Long Co., Inc. 2014 Grower Meeting, January 15, 2014, Yakima, WA.

Industry Presentations (Poster):

1. Adiputra, J., Swamy, P., Donda, B., Bagewadi, B., Natra, N. and **Naidu, R.A.** 2016. The prevalence of grapevine leafroll and red blotch diseases in Washington vineyards. Washington State Grape Society, November 10-11, 2016, Grandview, WA.
2. **Naidu, R.A.**, Natra, N., Akinbade, S., Bagewadi, B., Swamy, P., Adiputra, J.,Hottell, D., Garza, M., Ocampo, C. and Schultz, A. 2016. Tackling emerging soil-borne virus diseases in

Washington vineyards. Washington State Grape Society, November 10-11, 2016, Grandview, WA.

3. Adiputra, J., Swamy, P., Donda, B.P., Bagewadi, B., Natra, N., and **Naidu, R.A.** 2016. The relative distribution of leafroll and red blotch diseases in Washington vineyards. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
4. Swamy, P. and **Naidu, R.A.** 2016. Impacts of grapevine leafroll and redblotch diseases in commercial vineyards. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
5. **Naidu, R.A.**, Natra, N., Akinbade, S., Bagewadi, B., Swamy, P., Adiputra, J.,Hottell, D., Garza, M., Ocampo, C. and Schultz, A. 2016. Tackling emerging soil-borne virus diseases in Washington vineyards. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
6. Bagewadi, B., Ocampo, C., Movva, A., Hottell, D., Garza, M., Natra, N. and **Naidu, R.A.** 2016. Improving the Sanitary Status of Certified Mother Blocks in Washington State. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
7. Hottell, D., Garza, M., Ocampo, C., Bagewadi, B., Swamy, P. and **Naidu, R.A.** 2016. Gambling with Grafting: Do's and Don'ts. Washington Association of Wine Grape Growers 2016 Annual Meeting, Convention and Trade Show, February 9-11, 2016, Kennewick, WA.
8. Ball, T., Folwell, R., Walsh, D. and **Naidu, R.A.** 2015. Is 'Grape virus tax' hitting your pocketbooks? Washington Association of Wine Grape Growers 2015 Annual Meeting, Convention and Trade Show, February 10-13, 2015, Kennewick, WA.
9. Donda, B., Adiputra, J. and **Naidu, R.A.** 2015. Is it leafroll or red blotch? Washington Association of Wine Grape Growers 2015 Annual Meeting, Convention and Trade Show, February 10-13, 2015, Kennewick, WA.
10. Walker, L., Bagewadi, B., Swamy, P., Schultz, A. and **Naidu, R.A.** 2015. A new soil-borne virus disease in Washington vineyards. Washington Association of Wine Grape Growers 2015 Annual Meeting, Convention and Trade Show, February 10-13, 2015, Kennewick, WA.
11. Swamy, P., Donda, B., Adiputra, J. and **Naidu, R.A.** 2015. Is grapevine red blotch disease a bad omen for Washington vineyards? Washington Association of Wine Grape Growers 2015 Annual Meeting, Convention and Trade Show, February 10-13, 2015, Kennewick, WA.
12. **Naidu, R.A.** 2014. An update on grapevine viruses in Washington vineyards. Washington Association of Wine Grape Growers 2014 Annual Meeting, Convention and Trade Show, February 5-7, 2014, Kennewick, WA.
13. Donda, B., and **Naidu, R.A.** 2014. The threat of grapevine leafroll disease to healthy plantings in Washington vineyards. Washington Association of Wine Grape Growers 2014 Annual Meeting, Convention and Trade Show, February 5-7, 2014, Kennewick, WA.
14. Pack, J., Bagewadi, B., and **Naidu, R.A.** 2014. Studies on grapevine red blotch disease in Washington vineyards. Washington Association of Wine Grape Growers 2014 Annual Meeting, Convention and Trade Show, February 5-7, 2014, Kennewick, WA.
15. Wm. Kade Casciato and **Naidu, R.A.** 2014. Hands-on Learning Experiences with Growing Healthy Grapevines. Washington Association of Wine Grape Growers 2014 Annual Meeting, Convention and Trade Show, February 5-7, 2014, Kennewick, WA.

Workshops/Field days:

1. Industry Expansion Bottleneck: Where will you get your plants? Clore Center, Prosser, WA. October 27, 2016.
2. Harmonizing Grapevine Nursery Stock Certification Programs in the PNW Stakeholder meeting, The Dalles, OR, July 19 & October 19, 2016
3. Scouting for symptoms in vineyards. Ste. Michelle Wine Estates, Paterson, WA. May 22, 2015.
4. Red blotch and leafroll update. Ste. Michelle Wine Estates 2014 Winemaker Council Meeting, Prosser, WA. May 28, 2014.
5. Finding virus infected plants, symptoms, sampling, storing and testing. WAWGG Summer Tour "How Clean Plants are Made", IAREC, Prosser, WA. August 7, 2014.

Professional scientific meetings (Oral & Poster):

1. Adiputra, J., Swamy, P., Donda, B., Bagewadi, B., Natra, N. and Naidu, R.A. 2016. The prevalence of grapevine leafroll and red blotch diseases in Washington vineyards. 2016 American Phytopathological Society Annual Meeting, June 30-August 3, 2016, Tampa, FL.
2. Bagewadi, B., Ocampo, C., Movva, A., Hottell, D., Garza, M., Natra, N. and Naidu, R.A. 2016. Assessing the sanitary status of certified mother blocks in Washington State. APS Pacific Division Meeting, La Conner, WA. June 28-30, 2016.
3. Natra, N., Akinbade, S., Bagewadi, B., Swamy, P., Schultz, A. and Naidu, R.A. 2016. The current status of nepoviruses in Washington vineyards. APS Pacific Division Meeting, La Conner, WA. June 28-30, 2016.
4. Swamy, P. and Naidu, R.A. 2016. Impacts of grapevine leafroll and redblotch diseases in Washington vineyards. 67th American Society for Enology and Viticulture (ASEV) National Conference, June 27-30, 2016, Monterey, CA.
5. Donda, B., and **Naidu, R.A.** 2015. Sequence analysis of G*rapevine leafroll-associated virus 1* from Washington vineyards. 2015 American Phytopathological Society Annual Meeting, August 1-5, 2015, Pasadena, CA.
6. Walker, L., Bagewadi, B., Schultz, A., and **Naidu, R.A. 2015.** The occurrence of *Tobacco ringspot virus* in a wine grape (*Vitis vinifera* L.) cultivar in Washington State. 2015 American Phytopathological Society Annual Meeting, August 1-5, 2015, Pasadena, CA.
7. Adiputra, J., Donda, B. and Naidu, R.A. 2015. Grapevine Leafroll and Red Blotch Diseases in Washington Vineyards. 66th American Society for Enology and Viticulture National Conference 2015, June 15-18, 2015, Portland, OR.
8. Donda, B., Kesoju, S., McRoberts, N. and Naidu, R.A. 2015. Elucidating the spread of grapevine leafroll disease in newly planted vineyards. 66th American Society for Enology and Viticulture National Conference 2015, June 15-18, 2015, Portland, OR.
9. Swamy, P., Donda, B., Adiputra, J. and Naidu, R.A. 2015. Impact of grapevine red blotch disease in red-berried wine grape cultivars. 66th American Society for Enology and Viticulture National Conference 2015, June 15-18, 2015, Portland, OR.
10. Donda, B, Kesoju, S., McRoberts, N. and Naidu, R.A. 2015. Insights into the epidemiology of grapevine leafroll disease in cool-climate viticulture. The 8th International IPM Symposium, "IPM: Solutions for a Changing World," Salt Lake City, Utah, March 23-26, 2015.
11. Donda, B., Adiputra, J. and Naidu, R.A. 2015. Is it leafroll or red blotch? WSU Academic Showcase, March 27, 2015, Pullman.

12. Donda, B. and Naidu, R.A. 2014. Spatio-temporal spread of Grapevine leafroll disease in Washington vineyards. 2014 American Phytopathological Society Annual Meeting, August 9-13, 2014, Minneapolis, MN.
13. Swamy, P., Holt, T., Alexander, D., and **Naidu, R.A.** 2014. Biochemistry and Metabolism Metabolic changes during compatible host-virus interactions in a perennial fruit crop. Plant Biology 2014. American Society of Plant Biologists July 12-16, 2014. Portland, OR.
14. Naidu**, R.A.** 2014. An update on grapevine viruses in Washington vineyards. WSU Academic Showcase, March 28, 2014, Pullman.
15. Donda, B. and **Naidu, R.A.** 2014. The threat of grapevine leafroll disease to healthy plantings in Washington vineyards. WSU Academic Showcase, March 28, 2014, Pullman.
16. Pack, J., Bagewadi, B., and **Naidu, R.A.** 2014. Studies on grapevine red blotch disease in Washington vineyards. WSU Academic Showcase, March 28, 2014, Pullman.