

**Unified Grant Management for Viticulture and Enology
PROPOSAL FOR THE 2022-2023 FUNDING CYCLE**

AMERICAN VINEYARD FOUNDATION (AVF)

OREGON WINE BOARD (OWB)

1. Project Title: Grapevine trunk disease management for conventional and organic production

2. Principal Investigator(s):

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Co-PI: Patty Skinkis, Oregon State University, Department of Horticulture, 4017 ALS Building, 2750 SW Campus Way, Corvallis, OR 97331
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3. Cooperator(s): None

4. Objective(s) of Proposed Research or Outreach Project:

- 1) Compare the efficacy of fungicides and sealants in protecting pruning wounds
- 2) Test the effect of pruning time and subsequent wound protection length of both conventional and organic registered fungicides

5. Justification and Importance of Proposed Research or Outreach Project:

Grapevine trunk disease (GTD) is a disease complex that consists of the largest group of fungal pathogens causing disease and progressive vine decline. In our previous study from Oregon vineyards, we detected *Botryosphaeriaceae* spp., and *Phaeoacremonium* spp. in 72% and 21% of the surveyed vineyards, respectively; *Phaeomoniella chlamydospora*, *Cryptovalsa ampelina*, *Truncatella angustata*, *Seimatosporium lichenicola*, *Hormonema viticola* from 7% of the surveyed vineyards; and *Ilyonectria macrodidyma*, and *Pestalotiopsis* sp. from 3% of the surveyed vineyards. Pathogens in the family *Botryosphaeriaceae* spp. cause Botryosphaeria dieback, pathogens *Phaeoacremonium* spp. and *Phaeomoniella chlamydospora* cause Esca, *Cryptovalsa ampelina* cause Eutypa dieback, *Ilyonectria macrodidyma* cause Blackfoot disease, and the remaining fungal pathogens are associated with other GTDs. While several kinds of GTDs are present in Oregon vineyards, *Botryosphaeriaceae* spp. are most commonly present in both Willamette and Rogue Valley vineyards.

Grapevine trunk diseases are often considered an “old vine” disease; however, there is evidence of vines being infected at an early stage. In our previous study, we detected

Botryosphaeriaceae spp. from vineyards aged two years to 40 years old. In Oregon and other Pacific western regions, vineyard planting continues annually with new developments or replacement of older/unproductive blocks within a vineyard. In many cases, older vineyards carry the pathogen inoculum, and the younger vineyards are vulnerable to infection with fresh annual pruning wounds and weather conditions favoring pathogen development. It is important for growers of newly planted vineyards to stay informed about the GTDs situation in nearby vineyards. This allows them to take precautionary measures to protect young vines from chronic diseases which may be difficult to cure once established. Baumgartner et al. (2019) showed adoption of preventative measures at early stages of vine development is cost-effective as compared to the adoption of this practice at later stages.

Several synthetic, organic, inorganic, and natural products have been developed and tested for their efficacy to control GTDs, specially *Botryosphaeria dieback*, Esca complex, and *Eutypa dieback*. Many synthetic products were lab tested for efficacy in vitro, while few were tested in the field, or as wound protectants (Mondello et al. 2018). In this study, we propose to test some of these effective fungicides, including both conventional and organic fungicides, for the control of *Botryosphaeria dieback*. Since Rogue Valley and Willamette Valley offer different climatic conditions for *Botryosphaeria dieback* pathogens, we propose to replicate the activities for the proposed objectives in these two locations.

Prolonged rain events and/or high relative humidity cause spore release that provides the initial source of inoculum. The spores are dispersed by rain drops, wind, or vectors, and may infect grapevines through open wounds (Moyo et al. 2014; Gramaje et al. 2018; Mondello et al. 2018). Unfortunately, both pruning time and rain events occur simultaneously in the PNW, making vine pruning wounds most vulnerable to GTD pathogen infection. Our previous study found most of the *Botryosphaeriaceae* pathogen spore release occurred between December and February in both the Rogue Valley and the Willamette Valley. One mitigation practice to avoid infection is to prune late in spring to avoid high spore load. However, this shift of pruning timings as late as possible is not feasible for most commercial vineyards due to logistical challenges associated with labor shortages and time. Thus, we wanted to test typical pruning timing with repeated wound protection to see if there would be benefits to preventing GTD infection. In addition, replication of the trial in two regions allows us to evaluate wound protectant product longevity under wetter and drier conditions of the Willamette Valley and Rogue Valley, respectively.

In addition to the synthetic fungicides, we wanted to test the efficacy of biological control agents (BCAs), for organic production under Oregon conditions. Among several BCAs, *Trichoderma* spp. were mostly studied and are available in several commercial products (Di Marco and Osti 2007; Fourie and Halleen 2006; and Pertot et al. 2016). Powder formulations of *Trichoderma* spp. can be mixed with water and applied as a spray to protect wounds, or as a soil amendment through irrigation or soil drenching (Mutawila et al. 2016). *Trichoderma* are fungal BCAs that colonize the wood of pruned canes and compete against pathogenic fungal species for space and nutrients. *Trichoderma* products are found to be viable for up to a year under greenhouse conditions (Di Marco et al. 2004; Harman 2006; John et al. 2008). A recent study reported a higher efficacy (88-100%) of two *Trichoderma* species, *T. asperellum* and *T. gamsii*, in controlling

Eutypa and Botryosphaeria dieback pathogens in California vineyards (Blundell and Eskalen, 2021) with varying recovery rate of these BCAs. In our previous study, we tested the recovery of the same two *Trichoderma* spp. when applied on pruning wounds in late February in Oregon's Applegate Valley. However, we could not recover the BCAs after 14 days of application and thereafter. We hypothesized that the BCAs were washed off from the pruning wounds given a rain event two days after BCA application and the vines had active sap flow. Since several studies have reported higher efficacy of these BCAs, we believe these BCAs need to be tested with several combinations of timing and repeated application under Oregon conditions to offer a better recommendation for effective use of this product.

6. Procedures to Accomplish Objective(s):

Objective 1) Compare the efficacy of fungicides and sealants in protecting wounds

Sites and experimental design:

The study site will be a 0.49 ha (1.2 acre) vineyard located at the Southern Oregon Research and Extension Center (SOREC) near Jacksonville, OR (42° 20' N, 122° 56' W). The vineyard was planted in July 2017 with Pinot noir (clone 113) and Chardonnay (clone 75) grafted on 110R. The spacing (row x vine) is 2.7 x 1.8 m (9 x 6 ft.). There are 26 rows in the vineyard, each 36 vines in length. There are eight replicate blocks of each cultivar, each with 54 vines (6 rows and 9 vines per row). Vines are cordon trained, spur pruned, and trained on a VSP trellis.

The study site in the Willamette Valley will be a 0.25 ha (0.63 acre) vineyard block located at the OSU Woodhall Vineyard in Alpine, OR (44° 20' 24.412" N, 123° 24' 26.466" W). The vineyard was planted in 1984 with Chardonnay (clone 108) on its own roots. The vineyard spacing matches that of the SOREC vineyard at 9 x 6 ft. There are 11 rows per block with 52 vines per row. Vines are cane pruned and trained on a VSP trellis.

Chardonnay vines will be pruned in early February. Immediately after pruning, the wounds will be spray-treated with the following fungicide treatments at maximum labeled rate. The treatments will be applied in four replicate sets of vines arranged randomly within a block.

1. Topsin (FRAC 1)
2. Rally (FRAC 3)
3. Vitiseal
4. Topsin + Rally; followed by Vitiseal
5. BioTam
6. BioTam followed by Vitiseal
7. Non-treated control

Inoculated trial and data collection:

The treatment vines will be artificially inoculated with pathogens that cause Botryosphaeria

dieback. The spore suspension of these pathogens will be spray-inoculated to the pruning wounds immediately after fungicides application. A non-treated control treatment will include vines with water sprayed treatments followed by spore inoculation. The inoculated wounds will be visually monitored for the progress of disease development and presence of any external symptoms during the growing season. During autumn leaf fall, the internal cane (woody) tissues near the inoculated wound will be observed for any tissue necrosis. The tissues will be removed from the vine and plated in artificial media for the recovery and/or detection of *Botryosphaeriaceae* spp. using both culture- and PCR-based detection methods. The efficacy of treatments will be analyzed as percentage of disease incidence characterized by both symptoms data and percent recovery of inoculated pathogens from treated vines.

Objective 2): Test the effect of pruning time and subsequent wound protection length of both conventional and organic registered fungicides

Vineyard site and pruning treatments:

This study will be conducted in the same research vineyard at Southern Oregon Research and Extension Center in Central Point and Woodhall Vineyard in Alpine, OR. Similar to first objective, the treatment vines will be artificially inoculated with pathogens that cause *Botryosphaeria* dieback. The spore suspension of these pathogens will be spray-inoculated to the pruning wounds immediately after fungicides application. A non-treated control treatment will include vines with water sprayed treatments followed by spore inoculation.

Selected Chardonnay vines will be pruned at three separate timings: 1) Early December; 2) Early January; and 3) Early February. Within each pruning timing, the fungicide application will be designed to compare the required number of applications to provide the maximum wound protection (Table 1). For example, for the December pruning time, four treatments including December only application; December and January applications; December, January, and February applications; and a non-treated control will be tested. Considering December, January, and February are the months with maximum spore load in the environment (based on our previous findings), all of the December pruning treatments will receive spore inoculation in all three months at a monthly interval (Table 1). Altogether, nine treatments will be tested as a combination of pruning time and number of fungicide applications needed. One of the most effective fungicide treatments from both conventional and organic group identified in objective one will be used for the applications. The treatments will be applied in four replicate sets of vines, and this experiment will be repeated a second year in both locations.

Data collection and analysis:

The wounds will be visually monitored monthly for the progress of disease development and presence of any external symptoms. During autumn leaf fall, internal tissues near the inoculated wound will be observed and any tissue necrosis recorded. The tissues will be sampled and plated in artificial media for the recovery and/or detection of *Botryosphaeriaceae* spp. using both culture- and PCR-based detection methods. The efficacy of treatments will be analyzed as percentage of disease incidence characterized by both symptoms data and percent recovery of

inoculated pathogens from the treatment vines.

Table 1: Treatments including the combination of pruning and fungicide application timings

Pruning	Fungicide application^a	# of fungicide applications	Inoculation
December	December #1	1	December January February
	December #2 January	2	December January February
	December #3 January February	3	December January February
	No fungicide #4	0	December January February
January	January #5	1	January February
	January #6 February	2	January February
	No fungicide #7	0	January February
February	February #8	1	February
	No fungicide #9	0	February

^a Numbers denote the treatment ID for individual combination of pruning time and fungicide applications

7. Timetable for Project:

Task	2022 ^x			2023			2024			2025
	Early ^y	Mid	Late	Early	Mid	Late	Early	Mid	Late	Early
Objective 1										
Trial site preparation	■			■						
Pruning	■			■						
Treatment application	■			■						
Data collection and analysis			■			■				
Objective 2										
Trial site preparation			■	■		■	■			
Pruning			■	■		■	■			
Treatment application			■	■		■	■			
Data collection and analysis						■			■	
Reports, outreach and Education				■			■			■
Final report										■

^x Early = January through April; Mid = May through August; Late = September through December

^y Please note that this project starts before the funding decision is made on this proposal

8. Present Outlook and Estimated Success in Accomplishing Objective(s):

The research labs of Dr. KC and Dr. Skinkis are located in Central Point and Corvallis, OR for convenient access to the research vineyard sites in southern Oregon and Willamette Valley, respectively. Both have extensive experience in carrying out grapevine research and are involved in grape disease research and extension through OSU and the Oregon Wine Research Institute. Dr. KC recently completed a project funded by Oregon Wine Board where she generated information on GTD prevalence and spore release in Oregon vineyards. Based on these findings, the current research project is proposed. In addition, she has collected the specimen of fungal pathogens that were most commonly present in Oregon vineyards. These will be crucial resources for conducting GTD management trials. The proposed GTD management trials will be the next necessary steps to combat this disease under Oregon conditions. Availability of matured, experimental research vineyards in both southern Oregon and Corvallis adds to the success in accomplishing objectives of this project since it allows more flexibility in conducting disease management research with inoculation. Additionally, collaboration of Dr. Skinkis is instrumental for the success of this project since she is trained in viticulture and vine physiology research which involves many collaborative research projects with Willamette Valley wine grape growers. She is aware of

vineyards with problems of trunk diseases. Her collaboration will be important in conducting the research, interpreting results, and communicating research results to end-users in the Willamette Valley.

9. Outreach and Education:

The results obtained from these studies will be extended to the growers through local growers meeting, online reports, the *Pest Management Guide for Wine Grapes in Oregon*, the *PNW Plant Disease Management Handbook*, and scientific peer-refereed publications. Results will be shared through the Oregon Wine Symposium, Grape Day, and Southern Oregon Wine Symposium, all of which are popular educational events attended by both industry representatives and researchers annually. Summaries of this research will be provided in technical reports to industry through the Oregon Wine Research Institute's monthly online *Vine to Wine Newsletter* and the Oregon Wine Board's *Grapevine Newsletter*. The results from these studies will be presented to academic peers in annual meetings of American Phytopathological Society (APS) and APS-Pacific Division meetings. It is anticipated that the results will be published in plant pathology related scientific journals such as *Plant Disease* and/or *Crop Protection*; or in horticultural journals, such as the *American Journal of Enology and Viticulture* or *HortTechnology*.

10. Budget Support Summary by Objective(s):

Total request (Year 1): \$54,001 for OWB; \$70,987 for AVF

Personnel (Total \$35,367). Costs include salaries for a 0.49 FTE graduate research assistant (GRA) and one part time undergraduate research assistant whose 100% of time will be invested in the project in Drs. KC and Skinkis labs. The GRA will be advised by Dr. KC and co-advised by Dr. Skinkis. They will be responsible for designing experiments, applying treatments, disease monitoring, collecting and processing samples, analyzing data and preparing reports and manuscripts. The rate is shown for each year with a 3% increase annually.

The undergraduate research assistant will assist the GRA in samples processing, media preparation, pathogen isolation, DNA extraction and pathogen detection.

Employee Benefits (Total \$10,554 for OWB; \$27,540 for AVF). Costs to cover benefits for GRA and undergraduate research assistant at 36% and 12% respectively of base salary as per OSU policy. The total tuition for the GRA will be required for the full academic year (fall, winter, spring and summer terms). For those granting agencies not covering tuition (OWB), the tuition support will be sought from either the department of Horticulture, department of Botany and Plant Pathology, or the Oregon Wine Research Institute. For those granting agencies covering tuition (AVF), an additional \$16,255 is requested.

Supplies and Expenses (Total \$6,500). Supply costs include materials and supplies for Dr. KC's lab such as petri plates to culture fungi (20 boxes @ \$100/box = \$2,000), microbiological media to culture fungi (4 jars @ \$250/jar = \$1,000), other miscellaneous items for sampling, reagents and consumables for DNA extraction and PCR (\$2,000). Expenses related to research

plot management @ \$3,000 per acre is requested for ½ acre worth of vineyard for this trial at SOREC.

Travel (Total \$1,580). Costs to travel to research sites and local grower’s meeting for PIs and GRA (2,000 miles @ \$0.56/mile = \$1,120). Two days of Lodging (@\$140/night = \$280) and three days per diem (@ \$60/day = \$ 180) is requested for travel to Corvallis from SOREC during the treatment application at beginning of the year and sample collection at autumn leaf fall.

Additionally, in Year 2 and 3, funds are requested to cover travel for Dr. KC to present in American Phytopathological Society annual conference (Total \$2,062: 3 nights lodging @ \$226/night, 4 days per diem @ \$71/day, \$500 registration, \$500 airfare, \$100 incidentals). These estimates are generated based on OSU travel estimates for high-cost cities.

The projected budget for two additional years assumes a 3% inflation rate (as per OSU policy) from the requested year for all items.

The proposal will be submitted to OWB, and AVF.

11. Total Budget Request: Year 1: \$54,001 for OWB; \$72,256 for AVF

Items	% Time on Project	Request 2022-2023	Projected 2023-2024	Projected 2024-2025
Personnel				
Graduate Research Assistant (12 months)	0.49 FTE	26,407	27,199	28,015
Undergraduate research assistant (12 months) 640 hrs @\$14.00/hr	100 %	8,960	9,229	9,506
Employee benefits				
Graduate Research Assistant (36%)		9,479	9,763	10,056
Graduate Student Tuition (AVF only)*		16,986	17,496	18,020
Undergraduate research assistant (12%)		1,075	1,107	1,140
Supplies and Expenses				
Petri dishes to culture fungi		2,000	2,060	2,122
Microbiological media to culture fungi		1,000	1,030	1,061
Miscellaneous: sampling bags and tubes, reagents and consumables for DNA extraction and PCR		2,000	2,060	2,122
Plot fees		1,500	1,500	1,500
Travel				
In state to field sites and meetings		1,580	1,627	1,676
Out of state conference			2,062	2,124
TOTAL REQUEST - OWB		\$54,001	\$57,638	\$59,322
TOTAL REQUEST – AVF*		\$70,987	\$75,134	\$77,343

*The OWB does not cover tuition, but this expense is allowed by AVF.

12. Literature Cited:

1. Baumgartner, K, Hillis V, Lubell M, Norton M, and Kaplan J. 2019. Managing Grapevine Trunk Diseases in California's Southern San Joaquin Valley. *American Journal of Enology and Viticulture* 70:267-276.
2. Blundell, R, and Eskalen, A. 2021. Evaluation of biological and chemical pruning wound protectants to control grapevine trunk idseases pathogens *Eutypa lata* and *Neofusicoccum parvum*. *Plant Health Progress First Look* <https://doi.org/10.1094/PHP-08-21-0113-RS>
3. Di Marco, S., Osti, F., and Cesari, A. 2004. Experiments on the control of esca by *Trichoderma*. *Phytopathol. Mediterr.* 43: 108-115.
4. Di Marco, S., and Osti, F. 2007. Applications of *Trichoderma* to prevent *Phaeomoniella chlamydospora* infections in organic nurseries. *Phytopathol. Mediterr.* 46:73-83
5. Fourie, P. H., and Halleen, F. 2006. Chemical and biological protection of grapevine propagation material from trunk disease pathogens. *Eur. J. Plant Pathol.* 116:255-265.
6. Gramaje D., Urbez-Torres J. R., and Sonowski M. R. 2018. Managing Grapevine Trunk Diseases With Respect to Etiology and Epidemiology: Current Strategies and Future Prospects. *Plant Dis.* 102: 12-39.
7. Harman, G. E. 2006. Overview of mechanisms and uses of *Trichoderma* spp. *Phytopathology* 96:190-194.
8. John, S., Wicks, T. J., Hunt, J. S., and Scott, E. S. 2008. Colonization of grapevine wood by *Trichoderma harzianum* and *Eutypa lata*. *Aust. J. Grape Wine Res.* 14:18-24.
9. Mondello, V., Songy A., Battison E., Pinto C., Coppin, C., Trotel-Aziz, P., Clement C., Mugnai L., and Fontaine F., 2018. Grapevine Trunk Diseases: A Review of Fifteen Years of Trials for Their Control with Chemicals and Biocontrol Agents. *Plant Dis.* 102: 1189-1217.
10. Moyo, P., Allsopp, E., Roets, F., Mostert, L., and Halleen, F. 2014. Arthropods vector grapevine trunk disease pathogens. *Phytopathology* 104: 1063-1069.
11. Mutawila, C., Halleen, F., and Mostert, L. 2016. Optimisation of time of application of *Trichoderma* biocontrol agents for protection of grapevine pruning wounds. *Aust. J. Grape Wine Res.* 22:279-287.
12. Pertot, I., Prodorutti, D., Colombini, A., and Pasini, L. 2016. *Trichoderma atroviride* SC1 prevents *Phaeomoniella chlamydospora* and *Phaeoacremonium aleophilum* infection of grapevine plants during the grafting process in nurseries. *BioControl* 61:257-267.

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Biographical Sketch

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EDUCATION

Ph.D. 2013	North Dakota State University, Plant Pathology
M.S. 2009	North Dakota State University, Plant Pathology
B.S. 2005	Agriculture and Forestry University-Nepal, Agriculture

EXPERIENCE

10/2016-present	Assistant Professor, Oregon State University
08/2014-09/2016	Post-Doctoral Research Associate, University of Florida
02/2013-11/2014	Post-Doctoral Research Associate, North Dakota State University
08/2006-01/2013	Graduate Research Assistant, North Dakota State University

HONORS AND AWARDS

- The Distinguished Graduate Student in Agriculture, Fargo, ND, 2012
The honor society of Gamma Sigma Delta
- Recognition of High Scholarship, Outstanding Achievement or Service, Fargo, ND, 2010
The honor society of Gamma Sigma Delta
- First Place Award, Graduate Student Oral Competition, Ames, Iowa, 2009
North Central APS meeting
- Student Travel Award, Ames, Iowa, 2009
North Central APS meeting
- Recognition of Scholastic Achievement, Fargo, ND, 2008
The honor society of Phi Kappa Phi

SYNERGISTIC ACTIVITIES (Most recent)

1. **KC, A.N. 2022.** Grapevine Trunk Disease Research Findings in Oregon. Oregon Wine Symposium. Virtual meeting, February 16, 2022.
2. **KC, A. N. 2021.** Pear: Managing Gray Mold and Other Major Pear Decays in the Pacific Northwest. Washington State Tree Fruit Association 117th Annual Meeting and NW Hort. Expo. Virtual meeting, December, 07, 2021.
3. **KC, A. N. 2021.** Pythium root and crown rot disease in Hemp: Symptoms and management strategies. OSU-Hemp Newsletter, August 2021.
4. **KC, A.N. 2021.** Grapevine Powdery Mildew Management. Rogue Valley Wine Growers Association Technical Meeting. Virtual meeting, April 27, 2021
5. **KC, A.N. 2021.** Grapevine Trunk Diseases (GTDs) in Oregon Vineyards: A pilot project on epidemiology and management. Oregon Wine Symposium. Virtual meeting, February 16, 2021
6. **KC, A.N. 2020.** Grape Red Blotch Disease: What we learned and where do we go next? Grape Red Blotch Disease Webinar Series. December 15, 2020

7. **KC, A.N. 2020.** More into the Details of Grapevine Red Blotch Disease Diagnosis: When, Where, How, and Why? Grape Red Blotch Disease Webinar Series. November 24, 2020
8. **KC, A.N. 2020.** Disease Management 101. Hemp Growers Online Forum. Medford, OR July 07, 2020
9. **KC, A.N. 2020.** Grapevine trunk disease epidemiology. Southern Oregon Grape Symposium. Central Point, OR March 10, 2020
10. **KC, A.N. 2020.** Research Showcase: Postharvest Pathology - Current efforts and future directions. Northwest Pear Research Review. Yakima, WA. February 20, 2020
11. **KC, A.N. 2020.** Grapevine Trunk Disease in Oregon-present status and future prospects. Oregon Wine Symposium. Portland, OR. February 11, 2020
12. **KC, A.N. 2020.** SOREC research update on tree fruits and wine grapes. Oregon Vineyard Supply (OVS) Medford Growers Meeting. Medford, OR. February 06, 2020
13. **KC, A.N. 2020.** Fundamentals of disease management in commercial tree fruits production. Pesticide Recertification Course 2020. Central Point, OR. January 28, 2020

PUBLICATIONS (Most recent)

1. **KC, A. N., DeShields, J. B., Levin, A. L., Hilton, R., Rijal, R. 2022.** Epidemiology of grapevine red blotch disease progression in southern Oregon vineyards. *American Journal of Enology and Viticulture: In Press.*
2. **Copp, C.R., KC, A. N., and Levin, A. D. 2021.** Cluster thinning does not improve fruit composition in grapevine red blotch virus-infected *Vitis vinifera* L. *American Journal of Enology and Viticulture* 73: 55-66. doi: 10.5344/ajev.2021.21016
3. **KC, A. N., Rasmussen, A. L., and DeShields, J. B. 2021.** 1-Methylcyclopropene (1-MCP) preharvest application and its effect on storability of ‘Comice’ and ‘Bosc’ pears. *HortScience* 57: 24-31. <https://doi.org/10.21273/HORTSCI16250-21>
4. **Johnson, K., Temple, T. N., KC, A. N., and Elkins R. B. 2021.** Refinement of non-antibiotic spray programs for fire blight control in organic pome fruit. *Plant Disease: First Look.* <https://doi.org/10.1094/PDIS-07-21-1405-RE>
5. **DeShields, J. and KC, A. N. 2021.** Morphological and molecular characterization of *Alternaria* spp. isolated from European pears. *Plant Disease: Just Published.* <https://doi.org/10.1094/PDIS-10-20-2143-RE>
6. **KC, A. N., and Rasmussen, A. L. 2020.** In-season monitoring of postharvest rot pathogens on European pears (*Pyrus communis*) in Southern Oregon and subsequent management strategies. *Plant Health Progress* 21: 47-57. doi.org/10.1094/PHP-07-20-0057-RS
7. **Levin, A. D., and KC, A. N., 2020.** Water deficits do not improve fruit quality in grapevine red blotch virus-infected grapevines (*Vitis vinifera* L.) *Front. Plant Sci.* 11:1292 doi.org/10.3389/fpls.2020.01292
8. **Xavier, K., KC, A. N., and Vallad, G., 2020.** Fungicide application timing essential for the management of leaf spot and fruit rot on pomegranate (*Punica granatum*) in Florida. *Plant Disease* 104: 1629-1637. doi.org/10.1094/PDIS-10-19-2224-RE.
9. **KC, A. N., and Rasmussen, A. L. 2019.** First report of *Diaporthe rudis* causing fruit rot on European pears in USA. *Plant Disease* 103: 2132. doi.org/10.1094/PDIS-12-18-2184-PDN

10. Xavier, K., **KC, A. N.**, Peres, N., Deng, Z., Castle, W., Lovett, W., and Vallad, G., 2019. Characterization of *Colletotrichum* species causing anthracnose of pomegranate in the Southeast U.S.A. *Plant Disease* 103: 2771-2780. doi:10.1094/PDIS-03-19-0598-RE
11. Xavier, K., **KC, A. N.**, Crous, P. W., Groenewald, J. Z., and Vallad, G. E. 2019. *Dwiroopa punicae* sp. nov. (*Dwiroopaceae* fam. Nov., *Diaporthales*), associated with leaf spot and fruit rot of pomegranate (*Punica granatum*). *Fungal Systematics and Evolution* 4: 33-41. doi:10.3114/fuse.2019.04.04

TECHNICAL REPORTS AND EXTENSION PUBLICATIONS (peer reviewed)

1. **KC, A. N.** and DeShields, J. 2021. Evaluation of organic materials for fire blight management in pears. *Plant Disease Management Reports* 15:PF041.
2. Hernandez, M., DeShields, J., **KC, A. N.** 2020. Evaluation of postharvest fungicides for control of gray mold in European pears, 2019. *Plant Disease Management Reports* 15:PF039.
3. Thompson, A., Hilton, R., **KC, A. N.**, Pscheidt J. W., Rendon, D. 2019-2021. *Pest Management Guide for Tree Fruits in the Mid-Columbia Area*. Oregon State University Extension Service: EM 8203.
4. Skinkis, P. A., Pscheidt, J. W., Moretti, M., Peachey, E., Walton, V. M., **KC, A. N.**, Kaiser, C. 2018-2021. *Pest management guide for wine grapes in Oregon*. Oregon State University Extension Service: EM 8413.