2020 Alabama State Report
NCCC212 Small Fruit and Viticulture Research Cooperative Project
Dr. Elina Coneva

Objective 1: Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

1. Evaluation of UC Davis Developed Pierces Disease (PD) Resistant Predominantly *V. vinifera* Grapes in AL. E. Coneva, and M. Price, Auburn University, Auburn, AL, and Andy Walker, UC Davis.

2. Assessment of Recently Released Muscadine Grape Cultivars and Advanced Selections from the UoG breeding program in AL conditions. E. Coneva, M. Price, Auburn University, Auburn, AL, and P. Conner, UoG.

3. Assessment of Newly Released UoG Blueberry Cultivars, E. Coneva and M. Price, Auburn University, Auburn, AL, and Scott NeSmith, University of Georgia, Griffin, GA.

4. Evaluation of Newly Bred Seedless Table Grape Selections from the University of Arkansas Breeding Lines. E. Coneva, Auburn University, Auburn, AL; and John Clark, University of Arkansas.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

5. Determining the Optimal Planting Density of Pierces Disease (PD) Resistant Predominantly *V. vinifera* Grapes trained to a Watson training System in Alabama conditions. E. Coneva, and M. Price, Auburn University, Auburn, AL, and Andy Walker, UC Davis.

6. Evaluations of selected scion-rootstock combinations for sustainable hybrid bunch grape production in Alabama. E. Coneva and James Pitts, Auburn University, Auburn, AL.

Impact: The fruit industry in the state of Alabama is provided new knowledge on the performance of newly released and improved small fruit cultivars and the best production practices for enhanced sustainability and profitability of high-value specialty crops.

Viticultural Potential of Pierce's Disease-Resistant Predominantly *Vitis vinifera* L. Selection Grown in Central Alabama (Experiment 1 and 5**)**

Vitis vinifera grape production in the southeastern United States is limited by the endemic bacterium, *Xylella fastidiosa*, causal agent of Pierce's Disease (PD). Predominantly *V. vinifera* selection '502-20' bred at the UC Davis and grafted on 'Salt Creek' rootstock, was planted at three densities and trained to a Watson training system in the winter of 2017. The experimental plot is located at the Chilton Research and Extension Center in central Alabama. The goal is to determine the vine viticultural performance and the optimal planting density while utilizing the Watson training system. Vine survival in the high PD risk conditions of Alabama is also being assessed. Data is being collected to determine vine phenology, total yield, fruit quality and vigor of 'U0502-20' grape at each planting distance. Fruit cluster production was observed during the second growing season, when clusters were removed before flowering in order to encourage root system establishment of the young vines. The experimental vines were dormant pruned to 12 spurs per vine (6 spurs/cordon) with two buds per spur retained for a total number of 24 buds per vine. Shoot thinning was conducted during spring to maintain the desirable shoot number. Additionally, cluster thinning was applied to adjust the crop load to one cluster per shoot. The 'U0502-20' vines produced the first commercial crop during the 2019 season. Current season results for total yield per vine (Fig. 1, 2) suggest similar cropping level regardless of planting distances with the 6' in-row treatment producing 18.7 lb/vine, and the 7' and 8' in-row distance treatments producing 19.4 lb/vine. No statistical differences were found in cumulative yield per vine during 2019-2020, when the plants produced between 36.2 and 36.8 lb/vine. Mean cluster weight varied between 367.2 g for vines planted at 6' X 12' to 394.3 g for vines planted at 7' X 12' during the current season, when the number of clusters harvested per vine ranged from 27.7 for plants at 7' X 12' to 31.6 for vines at 8' X 12'. Mean berry size for all planting distances was slightly above 2.0 g with soluble solids content of 18.4-18.7 %.

Research will continue to more fully assess the vegetative and productive responses of PD resistant predominantly European grape 'U0502-20' and determine the optimal planting distance in Alabama conditions.

Assessment of Newly Released UoG Blueberry Cultivars in Alabama (Experiment 3**)**

Blueberries are a high value fruit crop and are becoming increasingly popular worldwide. In the last decade, Alabama's blueberry farm gate value has increased by approximately 13 percent. Research currently being conducted could determine that Alabama blueberry growers have several more varieties to choose from.

The blueberry breeding program at the University of Georgia, has released new blueberry varieties that have been created to keep up with the commercial and home garden demands. Some of these varieties include 'Titan' and 'Krewer', new large-fruited rabbiteye blueberry cultivars. The USDA released 'Pink Lemonade' rabbiteye blueberry possess a unique pink fruit color and ripens late.

A study plot was established in 2019 to test and compare ten well-established and newly released rabbiteye blueberry varieties for production in Alabama. This research, done at the Chilton Research and Extension Center, will evaluate the plants productivity and fruit quality under central Alabama growing conditions. The varieties evaluated in the study include:

- Titan
- Krewer
- Pink Lemonade
- Alapaha
- Climax
- Vernon
- Premier
- Powderblue
- Tifblue
- Oclockonee

Data on bloom period, cold hardiness, crop load, season of maturity, total yield, and fruit quality will be gathered over multiple growing seasons to establish cultivar growth, productivity, pest resistance, and overall adaptability to Alabama conditions.

Publications:

Journal Articles:

1. Andrej W. Svyantek*, **Elina D. Coneva**, J. Raymond Kessler, James D. Spiers, Edgar L. Vinson III, A. Walker, and James A. Pitts. 2020. Assessment of Pierce's Disease Resistant 87.5% *Vitis vinifera* L. Selections in Central Alabama. Catalyst Discovery Into Practice: https://www.asevcatalyst.org/content/early/2020/07/06/catalyst.2020.19008

2. Vinson, E.L. III*, **Elina D. Coneva**, Joseph M. Kemble, J. Raymond Kessler, Jr., Esendugue G. Fonsah, Penelope M. Perkins-Veazie, Floyd M. Woods and Jeff L. Sibley. 2020. Reflective Mulch Application and Cover Crop Usage to Stimulate Earlier Banana Flowering. J. Am. Pomological Society. 74(3): 169-179.

3. Jacob T.K., J.D. Spiers, J. R. Kessler, **Elina D. Coneva**, and E.L. Vinson. 2020. Effect of hydrogen cyanimide on flower production of 'AU Golden Sunshine' and 'AU Gulf Coast Gold' kiwifruit. Journal of the American Pomological Society. (Accepted).

1. Extension Publications:

E. Coneva. Novel grape varieties: https://www.thepacker.com/article/novelty-grapes-among-24-varieties-new-plus

E. Coneva. New Large-Fruited Blueberry Cultivars Evaluation: Alabama IPM Communicator Newsletter Volume 11, Issue 10, May 15, 2020:

https://www.aces.edu/blog/topics/crop-production/new-blueberry-varieties-being-tested-for-alabama-growers/

E. Coneva. ACES Your Friday - Dayli Briefing May 29, 2020 :

https://www.aces.edu/blog/topics/crop-production/time-to-watch-out-for-japanese-beetle/

E. Coneva. ACES Your Friday - Dayli Briefing May 29, 2020:

https://www.aces.edu/blog/topics/crop-production/mummy-berry-blueberry/

E. Coneva. May 29: IPM Communicator Vol. 11, Issue 11:

https://www.aces.edu/blog/topics/crop-production/time-to-watch-out-for-japanese-beetle/

E. Coneva. May 29: IPM Communicator Vol. 11, Issue 11:

https://www.aces.edu/blog/topics/crop-production/mummy-berry-blueberry/

E. Coneva. AL IPM Communicator, Volume 11, Issue 14: Grape root borer: https://www.aces.edu/blog/topics/crop-production/grape-root-borer/

E. Coneva. IPM article: Alabama IPM Communicator Newsletter Volume 11, Issue 17 https://www.aces.edu/blog/topics/crop-production/yield-and-fruit-quality-of-pierces-disease-resistant-grapes-in-alabama/

E. Coneva. CAESWEB SR SFC Newsletter October 15 Vol 20 No. 4 Fall issue: https://smallfruits.org/2020/10/assessment-of-pierces-disease-resistant-predominantly-european-grape-in-alabama/;

Appendix

Figure 1. Crop load and fruit quality of PD resistant predominantly European grape 'U0502-20' trained to a 'Watson' trellis system, grown at the CREC, Clanton, AL, 2020.

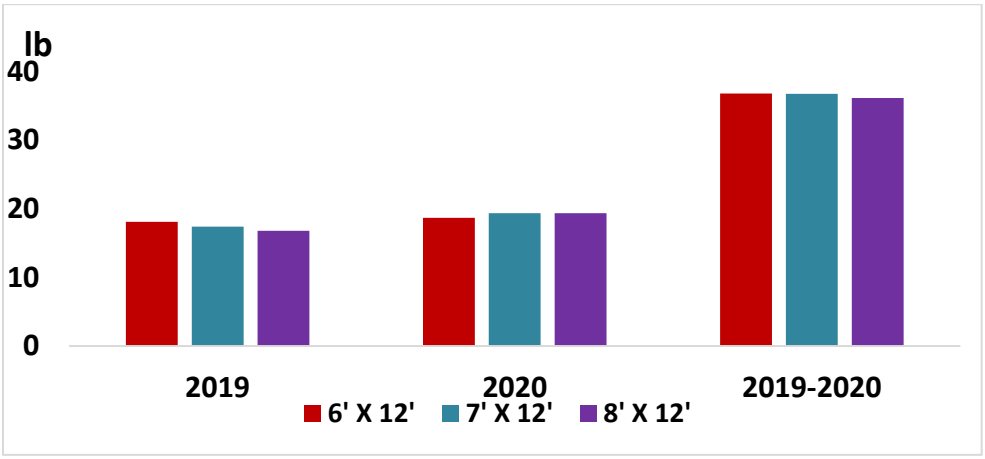

Figure 2. Total yield of PD resistant predominantly European hybrid 'U0502-20' grape trained to a 'Watson' system and grown at three planting distances at the CREC, Clanton, AL, 2019-2020.

DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

NCCC212: Small Fruit and Viticulture Research

2020 Report from the University of Arkansas

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Blackberry and Raspberry (Clark, Worthington, Threlfall, Lee):

The 2020 season was very productive. We had a relatively mild winter at the Fruit Research Station, Clarksville, and no significant cold damage was observed this year. The average temperatures throughout the spring and summer were typical and ripening time was average overall. May was very rainy (7.26 in), but only 1.6 in of rain fell during peak blackberry season in June. The breeding crew and FRS staff were diligent about following COVID-19 safety guidelines and we were able to perform crossing and evaluations as usual this year with just a few modifications. Blackberry seed numbers for 2020 were excellent.

Two new floricane-fruiting cultivars with excellent flavor have been released in the past few years. 'Caddo', a high-yielding thornless, erect cultivar with medium-large fruit that are sweet and flavorful was released in 2018. 'Ponca', a high-yielding thornless, erect cultivar with medium-sized fruit with enhanced sweetness and good post-harvest handling was released in 2019.

One additional primocane-fruiting selection has been submitted for release approval by the AES, APF-268, and when approval is complete, it will be available for sale. The projected first offer date is December 1. The proposed name is Prime-Ark® Horizon, and if all goes well, this will be the name. This release is intended to be a complement to Prime-Ark® 45 as it is thorny. The floricane fruit potential is very high, among the highest of any blackberry genotype tested in the Arkansas program. Primocane crop is lower, as is the reality with all primocane-fruiting cultivars in Arkansas. During testing, the primocane crop ranged from 10 to 74% of the floricane crop among years. APF-268 is large, and average berry size of floricane berries was 7.8 g and primocane berries 7.3 g. The similarity in berry size from these two cane types is much closer than any primocane-fruiting cultivar, and suggests more stable berry size stability in summer heat. Postharvest storage potential is good for this new development, particularly for firmness and low leakage; reversion is similar to Prime-Ark® 45. Finally, this new development fruits longer in the fall, averaging 8 days longer than Prime-Ark® 45 and 19 days longer than Prime-Ark® Traveler.

There are a number of other primocane- and floricane-fruiting blackberry selections in advanced stages of testing. We are also continuing work on breeding blackberries with novel or 'dwarf' architecture for home gardeners. Dr. Worthington has assumed leadership of the novel breeding program and is collaborating with U. Arkansas System Division of Agriculture Controlled Environment Horticulture Specialist Ryan Dickson on testing these materials in new intensive production systems.

We have also expanded molecular breeding and research activities in blackberry. University of Arkansas researchers are collaborating with NCSU (Dr. Hamid Ashrafi and Dr. Gina Fernandez), USDA-ARS (Dr. Nahla Bassil), and United Kingdom researchers on the development of two diploid reference genomes. Our team has completed two years of phenotyping on a blackberry genome-wide association study (GWAS) funded by USDA-AFRI and we are looking forward to analyzing genotype data by the end of 2020. Graduate students have measured thorn density, internode length, fruit size and shape, sweetness, acidity, seed size, firmness, and red drupelet reversion in a panel of ~300 UA breeding selections and cultivars for this GWAS project. We are also working with breeders and scientists at Pairwise, NCSU, USDA-ARS, Cornell, and Plant Sciences, Inc. on a unique public-private partnership to identify and characterize the genetic diversity in a diverse *Rubus* collection.

Grapes and Muscadines (Clark, Worthington, Threlfall, Lee):

Table and wine grape evaluation and muscadine breeding continues at the Fruit Research Station, Clarksville. As with blackberries, no substantial cold damage was observed in grapes or muscadines this season. Many of the muscadine vines in our research vineyard were severely damaged by auxin herbicide drift during June 2020. We also observed much more powdery mildew on muscadine fruit than usual in 2020. Despite these challenges, we had a productive season with promising new selections identified and excellent muscadine seed numbers from 2020 crosses.

Two new white wine grapes with Muscat and Gewürztraminer flavors are currently being prepared for release. Both of these white wine grape cultivars have shown good adaptation and consistent productivity in Arkansas. Enological evaluations have shown that these cultivars produced high-quality wines from fruit grown in Arkansas. It is envisioned that these cultivars will be a nice complement to the 'Enchantment' and 'Opportunity' wine grapes released by our program in 2016 and that they can expand options for unique wine grape offerings for growers and wine-makers in Arkansas and the Mid-South region. We anticipate that these new cultivars, 'Indulgence' and 'Dazzle', will be officially released and offered for sale this winter. There are also several table grape selections in advanced testing, but no immediate releases on the horizon.

Dr. Worthington is currently leading muscadine grape breeding. Several advanced selections have been identified and submitted for virus testing at the NCPN site in Raleigh, NC. We anticipate making our first release(s) in winter 2021/2022! 2020 was our fourth year of crossing with pollen from seedless selections from the Jeff Bloodworth/Gardens Alive! breeding program. We made our first seedless selection this September from crosses made in 2017. We are optimistic that improved textures and seedlessness will broaden the appeal of muscadine grapes for a broader consumer base and generate a lot of excitement in the Southern US and beyond.

Other ongoing research on muscadines includes measuring firmness of berries analytically and by sensory, validation of a new candidate gene for bronze berry color, investigations into the inheritance of sex and leaf shape in collaboration with Patrick Conner (UGA), and estimation of genetic diversity of wild and cultivated muscadines across the native range

Impact:

The major impact of the small fruit breeding effort is in plantings of released blackberry cultivars. The primocane-fruiting cultivars have had significant production now for several years and are now providing for a much-extended blackberry marketing season for domestic production. The floricane-fruiting cultivars Ouachita, Natchez and Osage are the most popular and continue to provide for high quality berries. The new releases Caddo and Ponca are expanding production also, and Ponca looks to be a big step up in consistent sweetness in berries

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Grapes:

High Tunnel Grape Production Systems: A Novel Sustainable Approach to Growing Grapes (Cooperators: D. T. Johnson, R. Threlfall UA; J. Lee, A. McWhirt, R. Rainey, UAEX; L. Freeman NCATT). SSARE R&E grant.

The purpose of this project was to investigate the efficiency and economic feasibility of using high tunnel technology as a tool for expanding table and wine grape production to areas where open field vineyard management requires high levels of inputs due to both biotic and abiotic challenges.

Objectives:

Objective 1. Evaluation of high tunnel grape cultural and pest management methods by investigating potential grape production management techniques
Objective 2. Determine marketable attributes through the evaluation of physiochemical, composition, and post-harvest attributes for high tunnel grapes
Objective 3. Develop economic budgets for high tunnel grape production
Objective 4. Generate production practices for high tunnel grape growers
Objective 5. Expand outreach efforts for high tunnel grape production

Impact:

Two MS students graduated in the spring of 2020

- Performance Evaluation of Four Arkansas Table Grape Cultivars Grown on Three Trellis Systems Under High Tunnels at Two Locations in Arkansas. Jose Hernandez
- Determining Cluster Thinning and Storage Effects on Fruit Quality and Marketability Attributes of Arkansas Table Grapes Grown Under High Tunnel Systems. Virginia Beasley

Grape food science activities (Threlfall)

- Physicochemical properties of wines and juices produced in from grapes grown in Arkansas (PhD Student Sarah Mayfield, defended 2020)
- Phylogenetic diversity of Arkansas vineyard and wine microbiota (PhD Student Natacha Cureau, defended 2020)
- Identifying unique attributes and postharvest practices for Arkansas muscadines (current MS student Cody Rawls)

Virtual Muscadine Workshop and Field Day hosted on September 18, 2020 (A. McWhirt and R. Threlfall, organizers and M. Worthington and A. Cato, speakers)

Strawberries:

Row covers and planting date for strawberry production 2018-2020 (A. McWhirt)

Objective for this trial was to compare the application of row covers at two timings in the fall to no row cover on both an on-time and late planting of Chandler. Ruby June and Fronteras were also used in the trial for single seasons. Trial was conducted at two locations in AR for the 2019 and 2020 harvest seasons.

- Plant size and yield observations support on-time planting date (before Oct. 5th in central AR) to maximize yield. Yield was on average 100g more per plant in on-time plantings relative to late plantings without row covers. Row covers may improve crown development and yield on late plantings relative to uncovered plants, but results did not indicate that row cover use on late plantings can result in yields equal to on-time planting dates. Row covers applied to on-time plantings did not impact yield.

Strawberry Variety Trial 2019-2020 (A. McWhirt)

Nine strawberry cultivars were evaluated at the University of Arkansas Vegetable Research Station (zone 7a) during the 2019-2020 season. Trial is being replicated in 2020-2021 with additional cultivars and advanced selections.

- Cold damage ratings after Nov 13th freeze (Temperatures dropped 40-50F overnight and was first major cold event of the fall). Moderate to severe damage observed in most cultivars. Reassessed cold damage during spring biomass sampling and observed lower levels of cold injury (indicating crown recovery from injury) in cultivars that previously had been rated as minor to moderate damage. Fronteras and Albion had severe cold damage ratings in the fall 2019 that persisted into the spring 2020. These two cultivars were also among the lowest yielding.
- Highest yielding cultivars: Camarosa, Rocco, Liz. Rocco and Liz had low cold damage ratings and low fall runner production at our site.

Strawberry IPM trials and pest management observations (Cato)

- Excessive rains led to statewide issues with anthracnose.
- Promax and Zap trial (Planted Fall 2020)
    - Assessing the effect of promax and zap rotations on soil pathogens and nematodes. We are also comparing these to some known standards.
- Assessing differences in diseases and pest abundance in many commonly grown cultivars and some new cultivars in the variety trial described above

Virtual Strawberry Field walk hosted April 20th, 2020 (McWhirt, Cato)

- https://www.youtube.com/watch?v=p_BFZaXdwIc&t=9s

Blackberries and Raspberries:

Rotating Cross Arm Trellis and Standard T-trellis Comparison. (A. McWhirt)

A comparison of varietal performance on both a rotating cross arm trellis and standard t-trellis is being conducted at the University of Arkansas Fruit Research Station in Clarksville, AR.

- 2019, 2020 first two full seasons of harvest data. Yield per plant is higher on the RCA vs standard for Ouachita and Osage cultivars. Yields per linear row foot and assessments of fruit quality are ongoing. Had higher incidence of white drupe in 2020, compared to 2019. Labor is being monitored between both systems and an economic report will be developed in 2021.
- MS Student Erika Henderson graduating Dec 2020, publications forthcoming

Preliminary evaluations of timing and rates of prohexadione calcium on blackberry (A. McWhirt, T. Kon (NCSU))

The trial evaluated high and low rates of prohexadione calcium applied starting a two different timings in early spring. Trial conducted at two locations in Arkansas, both on Ouachita.

- Impacts on primocane growth and yield on-going, preliminary observations indicate that material should not begin being applied until primocanes emerge.

Broad mite in blackberry and other pest management observations (Cato)

- Monitoring populations across the season in multiple locations across Arkansas. Broad mite was found state-wide in 2020, but not as serious as in 2021
- Project assessing the effect of post-harvest infestations on growth and yield of primocanes.
    - Infested and uninfested plots were established and will be monitored during the 2021 season.
- Very light year for Spotted Wing Drosophila.
- Large amount of cane lesions from Anthracnose on 2020 floricanes. This is likely due to record rainfall in 2019.
- Observations of yellow vein and other viruses are beginning to be much more common.

Evaluation of preemergent herbicides for newly planted blackberries (Bertucci, McWhirt, Cato. SRSFRC 2020 proposal).

Few preeemergent herbicides are registered for use on first year blackberry plantings. The majority of preemergent herbicides are restricted to plants that have been established for more than 1 year. New blackberry plantings, where plants are smallest and most vulnerable

to weed interference, have the fewest options for chemical weed control. Thus, this proposal is designed to assess tolerance of newly established blackberry plants to several preemergent herbicides.

Objectives of project:

1. To determine the effect of preemergent herbicide applications on establishment and growth of newly transplanted blackberry plants in AR and NC.
2. To generate data on weed control and crop response that can be utilized for regional recommendations and applications for supplemental labels for herbicides for blackberries grown in the southern region.

Herbicide treatments include simazine, pendimethalin, S-metolachlor, flumioxazin, and mesotrione. Preemergent herbicide applications will be made using a CO_2-powered backpack sprayer (8002 EVS flat fan nozzles), calibrated to deliver 20 gallons per acre covering a 40 inch swath on each side of the plot. All plants will be shielded during applications to ensure no herbicide reaches the foliage. Treatments will be applied within 72 hours after planting.

Impact
Results from this study will be used to guide recommendations for herbicide in new blackberry plantings, including the University of Arkansas Recommended Chemicals for Weed and Brush Control and the Southeast Regional Caneberries Integrated Management Guide. Data will also be used to solicit supplemental labels and 24(c) registrations for promising herbicides in the southern region.

Blackberry food science activities (Threlfall)

"Intelligent Soft Robotic Gripper for Fresh-Market Berry Harvesting" (University of Arkansas Chancellor's Innovation and Collaboration Fund grant)

- Robot gripper evaluated in 2019 and 2020

Consumer evaluation of six University of Arkansas blackberry cultivars. (Threlfall, Clark, Worthington)

- Consumers scored Ponca highest for overall impression and flavor
- Study results in press at Hort Science. See publication list

Identifying unique attributes and harvest practices that impact marketability of Arkansas fresh-market blackberries (MS student Andrea Myers)

Grower meetings and stakeholder outreach

AR Blackberry Growers Association, Winter Meeting Feb 8th, 2020. Little Rock, AR. Organized by A. McWhirt

US Blackberry Industry Strategic Planning Meeting. Funded by SCRI. Organized by M. Worthington

- Meeting held immediately following NARBA with discussion guided by results of a national stakeholder survey conducted during winter 2019/2020
- Industry and academic collaborators from all US blackberry production regions participated
- Survey results to be submitted for publication in HortScience. Manuscript in preparation
- Survey and planning meeting to guide development of full SCRI proposal for 2021/2022 cycle

Blueberry

Blueberry School Completed in late 2019. Trained 100+ agents and growers. Hosted by Bill Cline (NCSU) and Amanda McWhirt (UArk). Recording available online: www.uaex.edu/blueberryschool

Small Fruit Virology Activities

Ioannis Tzanetakis

- Validation of NGS technology for routine virus testing of G1 plants – even with NGS technology it is necessary to test plants for two seasons
- Field surveys to develop a list of 'canary viruses' affecting *Rubus* across the US was just completed - Results Are being analyzed
- New viruses of note: Two rhabdoviruses in strawberry (probably aphid-transmissible) and a carlavirus in blueberry - similar to blueberry scorch- looking at pathogenicity of the new viruses
- Improve diagnostics – major bottleneck the genetic diversity of berry viruses. There are many false negative- Example *Rubus* yellow net and tomato ringspot

Objective 3 - Explore the association between fruit constituents and human health impact

None

List publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications.

Brown, A., M. Worthington, A. Varanasi, L. Nelson, R.T. Threlfall, and L.R. Howard. 2020. Estimation of additive and dominance effects of a mutant glutathione S-transferase gene on anthocyanin content in muscadine grape (*Vitis rotundifolia*). Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences. 21:15-22.

Bushakra, J.M., L.A. Alice, K.A. Carter, M. Dossett, J.C. Lee, A. Liston, R. Meiers, C. Mulch, A.M. Nyberg, M. Peterson, K.J. Vining, M.L. Worthington, M.H. Yin, B.L. Sutherland, J.D. Zurn, J.R. Clark, C.E. Finn, N.V. Bassil, K.E. Hummer. 2020. Status of *Rubus* germplasm at the US National Clonal Germplasm Repository in Corvallis, Oregon. Acta Hort. 1277:121-128.

Clark, J.R., M. Worthington, and T. Ernst. 2019. 'Caddo' thornless blackberry. HortScience 54:1632–1636.

Delić, D., M. Radulović, M. Vakić, A. Sunulahpašić, D.E.V. Villamor, and I.E. Tzanetakis. 2020. Raspberry leaf blotch emaravirus in Bosnia and Herzegovina: population structure and systemic movement. Mol. Biol. Rpt. 47:4891–4896

Delić, D., M. Radulović, M. Vakić, A. Sunulahpašić, D.E.V. Villamor, and I.E. Tzanetakis. 2020. First report of black currant reversion virus and gooseberry vein banding associated virus in currants in Bosnia and Herzegovina. Plant Dis.104:2036

Felts, M., R.T. Threlfall, J. Clark, and M. Worthington. 2020. Effects of harvest time (7:00 AM and 12:00 PM) on postharvest quality of Arkansas fresh-market blackberries. Acta Hort. 1277:477-486.

Finn, C.E., M.E. Peterson, J.R. Clark, G.E. Fernandez, H.K. Hall, and M.L. Worthington. 2020. Merging blackberry germplasm pools and moving previously unutilized species into commercially viable selections. Acta Hort. 1277:47-54.

Foster, T.M., N.V. Bassil, M. Dossett, M.L. Worthington, and J. Graham. 2019. Genetic and genomic resources for *Rubus* breeding: a roadmap for the future. Hort. Res. 6:1-9.

Fuchs, M., C.V. Almeyda, M. Al Rwahnih, S.S. Atallah, E.J. Cieniewicz, K. Farrar, W.R. Foote, D.A. Golino, M.I. Gómez, S.J. Harper, M.K. Kelly, R.R. Martin, T. Martinson, F.M. Osman, K. Park, V. Scharlau, R. Smith, I.E. Tzanetakis, G. Vidalakis, and R. Welliver. 2020. Economic studies reinforce efforts to safeguard specialty crops in the United States. Plant Dis. *In Press.* https://doi.org/10.1094/PDIS-05-20-1061-FE

Lewter, J., M. Worthington, J.R. Clark, A.V. Varanasi, L. Nelson, C.L. Owens, P. Conner, G. Gunawan. 2019. High-density linkage maps and loci for berry color and flower sex in muscadine grape (*Vitis rotundifolia*). Theor. Appl. Genet. 132:1571–1585.

Molina-Bravo, R., M. Worthington, and G.E. Fernandez. 2019. Advances and challenges in raspberry and blackberry breeding. In: Lang, G.A. (ed.). Achieving sustainable cultivation of temperate zone tree fruits and berries. Volume 2. Burleigh Dodds Science Publishing, Cambridge, UK.

Spak. J., I. Koloniouk, and I.E. Tzanetakis. 2020. Graft-transmissible diseases of *Ribes* – pathogens, impact and control. Plant Dis. *In Press.* https://doi.org/10.1094/PDIS-04-20-0759-FE

Thekke-Veetil, T., T. Ho, J.D. Postman, and I.E. Tzanetakis. 2020. Comparative analysis of a new blackcurrant waikavirus with other members of the genus. Eur. J. Plant Pathol. 175:59-64.

Threlfall, R., J.R. Clark, A. Dunteman, and M. Worthington. 2020. Identifying marketable attributes of fresh-market blackberries through consumer sensory evaluations. HortScience. *In Press.*

Threlfall, R.T., A. Dunteman, J. Clark, and M. Worthington. 2020. Using an online survey to determine consumer perceptions of fresh-market blackberries. Acta Hort. 1277:469-476.

Worthington, M.L. and J.R. Clark. 2020. Development of blackberry cultivars with novel plant architecture. Acta Hort. 1277:159-164.

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Zurn, J.D., M. Driskill, S. Jung, D. Main, M.H. Yin, M.C. Clark, L. Cheng, H. Ashrafi, R. Aryal, J.R. Clark, M. Worthington, C.E. Finn, C. Peace, A. Iezzoni, and N. Bassil. 2020. A Rosaceae family-level approach to identify loci influencing soluble solids content in blackberry for DNA-informed breeding. Genes Genet. Genomes. 10:3729-3740.

BC Report to the NCCC 212 committee on small fruit and viticulture – October 2020

Objective 1: Develop improved small fruit germplasm through cooperative breeding and evaluation programs

1. British Columbia Berry Breeding Program: Dr. Michael Dossett, BC Blueberry Council (BCBC), Raspberry Industry Development Council (RIDC), BC Strawberry Grower's Association (BCSGA)

The BC breeding program focuses on blueberries, raspberries, and strawberries, and is led by the industry associations, in cooperation with Agriculture and Agri-Food Canada (AAFC), using levy dollars as matching funds for grants.

This year's biggest challenge was access to lab and field facilities due to the COVID-19 Pandemic. The program was able to successfully mitigate much of this and was able to continue with crosses and harvesting trial plots. Planting new trial plots was delayed but still proceeded. Molecular projects in the lab have been put on hold because of COVID, but we plan to start resuming those activities early in the new year. Unfortunately, the COVID situation limited access to greenhouses during the time in which trial material was slated to be sent to nurseries for contract propagation, so we are expecting a delay in when trial plants for the next round of advanced selections will be ready.

Blueberries

New seedling selections in the program continue to be noted for making progress in fruit size and quality, particularly firmness. Due to the COVID-19 pandemic, we were unable to do our usual bruising assays in the lab. Pollination across the region was hampered by a week of cool showery and blustery weather followed by a very unusual weather pattern for 3 days with very warm temperatures (87° F) and a strong sustained east wind during peak bloom. This weather discouraged bee activity and dramatically shortened the receptive period of flowers that were open. We were monitoring flowering closely during this period as we were doing emasculations and crosses daily in the breeding plots and this weather caused flowers to progress from opening to corolla fall in 48 hours or less.

Yield data is still being analyzed, but one selection is being scrutinized particularly closely. BC 14-40-158 has medium-large fruit and excellent quality. It ripens shortly after Draper in the Bluecrop season. Firmness is similar to Draper. It initiates flower buds earlier than most selections with fat flower buds often apparent in early-mid August. As a result, it initiates flower buds over an exceptionally long length of the new growth, often for as many as 25 nodes or more from the shoot tip, and has shown the potential to have very high yields. Tests this last season showed that it had good self-fertility with no deficit in fruit size from selfed flowers as compared to crosses with Duke, Draper, Bluecrop, and Elliott. On some sites it showed good pollination while on others it showed poor pollination this last season. We will continue to evaluate it for potential. Two selections,

BC 14-8-76 and BC 12-6-8 will be distributed for trial plantings as part of the collaborative CBTN trials (see below) in the spring. BC 14-8-76 is slightly later than Duke but is firmer and larger. BC 12-6-8 is exceptionally firm and ripens slightly later than Draper. It has an upright vase-shaped growth habit and somewhat willowy growth but does not yield well on younger wood.

Raspberries

In the 2017 Machine Harvest Trial, BC 10-71-27 (1.55 kg/plant) was the highest yielding selection, followed by WSU 2188 (1.24 kg/plant), compared with the standard 'Chemainus' (1.04 kg/plant). Both harvested exceptionally well by machine and had good fruit quality. BC 10-71-27 was about a week earlier than WSU 2188. In the 2018 Machine Harvest Trial, WSU 2069 (2.12 kg/plant) and BC 13-31-9 (2.03 kg/plant) were the standouts, with significantly more fruit than 'Meeker' (0.46 kg/plant) or 'Chemainus' (1.21 kg/plant). Both had nice quality, with WSU 2069 being especially nice.

We are currently conducting a large study to examine heritability and correlations between various yield components, yield, fruit quality, and seasonality. The aim is to try to identify selection criteria that will allow us to more effectively put selection pressure on yield and earliness simultaneously, an objective that is difficult because these two traits are negatively correlated. We also received funding in 2020 to work with an economist to help develop a selection index based on grower profitability. As the breeding program continues to increase the proportion of selections that machine harvest easily and show nice quality, this will further help separate those which are worth pursuing and those which are candidates for elimination by estimating and ranking their economic potential for growers and more accurately taking into account economic tradeoffs such as yield with earliness (greater percentage of fruit into IQF grade before processors stop taking IQF fruit for the season in favor of blueberries).

Strawberries

Our strawberry trials this season included our first look at advanced selections from the breeding program in Kentville as well as some of their new releases. Of the new releases from Kentville, the June-bearing AAC Kate was very large and had particularly nice fruit quality, though we noted that the fruit size dropped off and there was a big mix of sizes that needed to be sorted/graded after the primary berries were gone. Our day-neutral selection BC 10-2-1 performed well with yields that were better than Albion and which came back into bearing about a week earlier in July after the first flush. Unfortunately, we noted that BC 10-2-1 seemed to be significantly more prone to fruit damage from rain than Albion, with cracks and subsequent decline in fruit quality being noted. As a result, it is likely that it will not find a home for open field production and may be limited to situations where it is protected by high or low tunnels.

2. Canadian Berry Trial Network: Dr. Beatrice Amyotte, Research Scientist, AAFC's KRDC (Nova Scotia); Dr. Pierre Lafontaine, Director, Carrefour Industriel et Experimental de

Lanaudiere, and Jennifer Crawford, Executive Director, Association des Producteurs de Fraises et Framboises (Quebec); Dr. John Zandstra, Professor, University of Guelph (Ontario); Dr. Eric Gerbrandt, Plant Scientist, Sky Blue Horticulture Ltd. (BC).

The final stage of the breeding program prior to commercialization is to evaluate advanced selections under commercial conditions through grower trials. This portion of the program has been linked with programs in Ontario, Quebec and Nova Scotia to build a network of trials, each region evaluating the other's selections against standard cultivars. Two initial rounds of exchange of raspberry and strawberry selections and cultivars took place in 2019 and 2020 with selections from the Kentville and BC programs being distributed for replicated trials in each province. A first round of blueberry trials is being planned for spring of 2021. These trials will implement replicated comparisons of a range of industry standard cultivars, new cultivars, and non-commercialized selections from a few different breeding programs.

On-farm grower trial evaluations of existing raspberry, strawberry and blueberry trials. In 2020, this included intensive sampling to compare blueberry fruit firmness over five weeks in cooler storage.

Objective 2: Develop practices for small fruit production tailored for climatic and market needs of growers

1. Developing a decision support system for mitigating fruit rot diseases of berries: Dr. Rishi Burlakoti, Research Scientist, Agassiz Research and Development Centre (ARDC), Agriculture and Agri-Food Canada (AAFC)

In Agassiz Research and Development Centre (ARDC) and at the Clearbrook substation, fruit rot forecasting model prototypes were deployed to compare the model-based fruit rot infection risk and fruit rot incidence in fields. In Agassiz, one field trial for blueberry ('Bluecrop') and raspberry ('Meeker' and 'Chemainus') were conducted to evaluate the model-based fungicide spray and calendar-based fungicide spray programs in managing fruit rots of raspberry and blueberry. Fruit rot were assessed by collecting fruit samples from multiple varieties of blueberry (including selections from the BC Berry Breeding Program in Abbotsford) from both sites. Blueberry and raspberry fruit samples were also collected from growers' fields from diverse regions and fruit rot was assessed.

2. Managing berry root health through pathogens characterization, developing screening methods, and exploring good management options: Dr. Rishi Burlakoti, Research Scientist, Agassiz Research and Development Centre (ARDC), Agriculture and Agri-Food Canada (AAFC)

Two field trials, each at ARDC and a grower's field in Abbotsford, were conducted to evaluate different fungicide products in managing the root rot complex of raspberry. In Agassiz, confined field areas were built to inoculate with pathogens and evaluate the effects of control products, whereas a naturally infected site was used in a grower's field in Abbotsford. Treatments were applied in the spring and foliar symptoms were assessed at both sites. In addition, several growers' raspberry fields in Abbotsford were monitored to assess the root rot and wilting complex, and infected plant material were collected to isolate the causal agents.

3. 4. Integrating host resistance and alternatives to copper-based products for sustainable management of bacterial blight: Dr. Rishi Burlakoti, Research Scientist, Agassiz Research and Development Centre (ARDC), Agriculture and Agri-Food Canada (AAFC)

A long-term field trial was maintained in spring and summer. Isolates of *Pseudomonas* collected in 2018 and 2019 were revived regularly from long-term storage to maintain isolates. Blueberry fields at the research centre and in growers' fields were visited to monitor for bacterial blight and to collect disease samples.

4. Monitoring of arthropod pests in raspberry and blueberry germplasm: Dr. Michelle Franklin, Research Scientist, Agassiz Research and Development Centre (ARDC), Agriculture and Agri-Food Canada (AAFC)

The objective of this project is to provide the BC berry breeding program with information on the relative susceptibility or resistance of advanced selections to key arthropod pests will inform decisions about release and management of new cultivars of blueberry and raspberry. Analysis of the first year of data from 2019 suggests that there may be differences in susceptibility to aphids among cultivars that appear to be repeatable across sampling sites, with some new selections of blueberries consistently having lower aphid population densities than standard cultivars ('Duke', 'Bluecrop'). More years of data are needed, however, before these trends can be considered reliable. We are also exploring the potential for implementing binomial sampling plans for aphids in BC berries, which could greatly facilitate future evaluations, and initial results are promising.

5. Improving establishment of blueberry and raspberry with non-traditional crop inputs: Dr. Eric Gerbrandt, Plant Scientist, Sky Blue Horticulture Ltd.

For blueberry and raspberry, the objective of this project is to enhance crop establishment, yield and fruit quality through comparison of drench applications of four classes of alternative crop inputs (i.e., high P fertilizer, phosphites, humic acids and kelp extracts). Following pilot trials using potted plants, large replicated-field trials were established for blueberry and raspberry in 2017 and 2018, respectively. In 2020, the

blueberry component of this trial is in its fourth field season. Collection of field data from each experimental plot included soil sampling, leaf and fruit tissue sampling, harvesting of all fruit and measuring fruit quality parameters (e.g., average fruit size, firmness and shelf-life). For the raspberry component of this project, a third field season included soil sampling, leaf and fruit tissue sampling, harvesting of all fruit to assess yield and measuring fruit quality parameters (e.g., average fruit size).

6. Mitigating cultivar-specific physiological challenges in new blueberry cultivars: Dr. Eric Gerbrandt, Plant Scientist, Sky Blue Horticulture Ltd.

A first aspect of this project is focused towards solving specific fruit quality issues being seen in newly introduced blueberry cultivars, such as reducing splitting, shriveling and loss of firmness in cooler storage with a focus on 'Calypso', 'Last Call' and 'Cargo'. A third year of implementing differential irrigation and fertilizer rates in new cultivars of blueberry was used to complete the current set of trials. This included determination fruit size, resistance to splitting, and firmness during cooler storage.

A second aspect of this project is aimed at characterizing the heritability of Green Fruit Drop (GFD) in advanced selections in the BC Berry Breeding Program with the long-term goal of developing molecular markers to screen for this physiological disorder. To address the issue of GFD in 'Draper' blueberry (and other cultivars and breeding selections with 'Draper' in their pedigree), a region-wide survey of leaf and fruit nutrient allocation continued into a fourth season. Also, GFD management trials were implemented across multiple sites to evaluate transferability of an effective foliar calcium solution developed for GFD on 'Draper' to one new cultivar (Valor™) and one advanced breeding selection (BC 14-40-158) with 'Draper' in their pedigree.

7. Management of soil-borne pests and diseases in raspberry and strawberry: Dr. Eric Gerbrandt, Plant Scientist, Sky Blue Horticulture Ltd.

This project seeks to improve management tools for soil-borne pests and diseases, especially nematodes and Phytophthora root rot, to increase fruit yield and quality in raspberry and strawberry. In 2020, a new set of field trails was initiated to compare the effects of three different pest control products for their effects of plant parasitic nematodes and plant growth responses to soil-borne disease pressure. Nematode populations were assessed prior to trial implementation, and they are currently being re-evaluated after application of experimental treatments.

8. Implementing Integrated Pest Management Practices on Small-Scale Farms: Marjolaine Dessureault, Research Director, ES Cropconsult Ltd.

Working with blueberry, raspberry and strawberry growers, this project's objective is to develop IPM training materials for small-scale fruit and vegetable growers to handle shifts in pest pressure due to climate change and to improve region control. A short-list of target

pests was identified this season and will be used to develop grower education materials in the next year. A short-list of target pests was identified in 2019. In 2020, this project developed IPM management guides for 14 different pests.

9. Ecological Pest management for Spotted Wing Drosophila: Dr. Juli Carrillo, Assistant Professor, University of British Columbia

With support from the blueberry, raspberry and strawberry industries, this project is aimed at developing alternative methods of SWD control to reduce regional pressure and reliance on chemical tools. This includes the evaluation of intercropping options to repel SWD, developing better attractants for lures and traps and the establishment of effective biological control species in the region.

10. Evaluating mass trapping as a tool for non-chemical spotted wing drosophila management: Allyson Kang, IPM Consultant, ES Cropconsult Ltd.

The objective of this project is to evaluate mass trapping as an option for reducing SWD pressure in conventional and organic settings. In 2019 and 2020, this study was conducted in fields of 'Draper', 'Bluecrop' and 'Liberty'.

11. Non-Chemical Vole Control in Berry Fields: Sofi Hindmarch, Project Coordinator, Fraser Valley Conservancy

The objective of this project is to assess the effectiveness of a non-chemical option for killing voles. The project is using a commercial trap that has a self-resetting and has a bolt-action kill mechanism with the potential to reduce impacts on non-target wildlife as compared to rodenticides.

12. Assessing Harvest and Postharvest Fruit Quality in Blueberry: Dr. Simone Castellarin and Dr. Anubhav Pratap Singh, University of British Columbia

The objectives of this project are to assess fruit quality of current blueberry cultivars as well as advanced selections from the BC breeding program at harvest and at various times postharvest during cooler storage. This will permit the determination of biochemical constituents of fruit quality and how they change over time. This project also includes evaluation and development of postharvest treatments and advanced packaging materials for their ability to improve shelf-life will be used to improve shipping range for industry standard cultivars. In 2019 and 2020, fruit samples of selections from the breeding program as well as standard cultivars from commercial fields were provided to this research group for the first year of this study. Analysis of first year data is currently underway. There is a team of graduate and post-doctoral researchers working on various projects to elucidate the biochemical basis for fruit quality and develop post-harvest storage methods to extend fresh market shelf life.

13. Evaluation of spray-induced gene silencing of blueberry scorch and shock viruses as a method to reduce virus number and symptoms of infected blueberry plants: Dr. Jim Mattsson, Associate Professor, Simon Fraser University

The objective of this project is to design a biopesticide that can be used to prevent the spread of economically important blueberry viruses. The approach is to sequence the genetic code of the virus and then design RNA sequences that can inhibit replication of the virus when sprayed on the plant – spray-induced genomic silencing (SIGS).

14. Determining Optimal Wildflower Patch Arrangements to Minimize Pollination Deficits in Cultivated Blueberry: Dr. Rebecca Tyson, Associate Professor, University of British Columbia.

The objectives of this project include developing mathematical models of bee behaviour within blueberry fields to determine optimal placement of wildflower patches to foster native bumblebee populations to supplement honeybee activity during the blueberry pollination window; and analyzing pollen from "bee boxes" buried around blueberry fields to determine bumblebee movement in the landscape surrounding blueberry fields.

15. Controlling Blueberry Fruit Development using Plant Growth Regulators: Dr. Charitha Jayasinghege, Research Scientist, Agriculture and Agri-Food Canada

The objective of this upcoming project is to use plant growth regulators to de-blossom new plantings as well as delay the ripening season for various blueberry cultivars to shift the harvest window. This project was temporarily placed on hold due to COVID.

16. Development of Molecular Diagnostics for Plant-Parasitic Nematodes in BC: Dr. Tom Forge, Research Scientist, Agriculture and Agri-Food Canada

This project is aimed at development of a lab method for detecting nematodes in soil and root samples, filling a gap in diagnostic capacity for the local industry. This project was temporarily placed on hold due to COVID.

17. Development of PCR Based Methods to Reliably Distinguish Shock or Scorch Virus Infected Blueberry Plants: Dr. Jim Mattsson, Associate Professor, Simon Fraser University

The goal of this project is to determine strain variation for blueberry shock and scorch viruses to improve reliability of diagnostic tools available to the industry. This project addresses the potential issue of novel viral strains that are not detectable with the current version of the ELISA diagnostic test.

18. Effects of Host, Pathogen, and Environmental Factors on Increased Incidence of European Foulbrood in Honey Bee Colonies Pollinating Blueberries in BC: Dr. Sarah Wood, University of Saskatchewan

This project is focused on determining the effects of common pesticides on bee susceptibility to European foulbrood disease and assessing ways to improve bee nutrition and health.

NOT FOR DISSSEMINATION

Breeding and Genetics of Strawberries in Florida - Vance M. Whitaker, UF

All projects are under NCCC 212 **Objective 1**: Develop improved small fruit germplasm through cooperative breeding and evaluation programs.

Cultivar Development – collaborators include Dr. Christie Almeyda, NC State; Dr. Kim Lewers, USDA-ARS, Beltsville, MD; Dr. Gina Fernandez, NC State.

Impact Statement: UF strawberry varieties 'Florida Brilliance' (released 2017; 55% of acreage) and Sensation® 'Florida127' (released 2013; 35% of acreage) together make up about 90% of the 10,000 acres of strawberries grown in central Florida. Driscoll's proprietary varieties continue to be about 10% of acreage. Several multistate breeding and trialing collaborations are in place as detailed below.

In terms of cultivar development and release efforts, we continue to work collaboratively with the NCPN by sending tissue cultures of released varieties to the NC State micropropagation unit. A collaborative germplasm exchange with Dr. Kim Lewers, USDA, Beltsville, MD, was officially established in 2020 in which crosses are being made between UF and USDA accessions to combine flavor from the USDA parents and *Colletotrichum gloeosporioides* resistance from UF parents. Gina Fernandez of NC State continues to trial our new varieties as they become available in order to provide recommendations to growers in the mid-Atlantic. Thus far the newer UF varieties flower too early in the winter in this region.

Latest Releases Commercialized

Impact Statement: Two new UF strawberry cultivars have been released and patents applied for in July, 2020. These are detailed below. Trade names are in process.

'FL 16.78-109' (PPAF) is a new strawberry variety that produces extremely unique white-colored fruit with a pink blush. This variety will provide strawberry growers and marketers with new opportunities in retail and food service markets. 'FL 16.78-109' fruit are consistently sweet throughout the season and have a unique aroma reminiscent of apricot and pineapple. The first

plants have been planted in October 2020 and limited quantities of fruit will be available in select retail markets throughout this winter.

'FL 16.30-128' (PPAF) is a new strawberry variety that is intended to complement the production of 'Florida Brilliance' and Sweet Sensation (R) 'Florida127' and give growers another variety alternative with excellent early-season yields. Fruit of 'FL 16.30-128' are medium-large sized, firm, uniformly shaped, and have exceptional color and flavor.

Table 1. Marketable yield and average fruit weight of 'Florida Brilliance', Sensation® 'Florida127' and FL 16.30-128 at the University of Florida Gulf Coast Research and Education Center (GCREC) at Wimauma, FL during two seasons.

Cultivar	Marketable yield (g/plant)													
	November		December		January		February		March		Total		Wt/fruit(g) [z]	
2018-19														
FL Brilliance	21.4	a[y]	118.9	a	140.9	a	558.3	a	173.5	a	1013.0	a	28.1	b
Florida127	30.5	a	28.6	c	75.8	b	557.3	a	152.1	a	806.2	b	30.4	a
FL 16.30-128	19.3	a	74.4	b	103.3	ab	390.8	b	114.1	b	740.0	b	26.6	b
2019-20														
FL Brilliance	4.3	b	104.0	a	180.7	b	436.3	a	180.7	a	905.8	a	22.4	c
Florida127	8.3	a	80.2	b	259.8	a	446.7	a	141.3	b	936.2	a	27.3	a
FL 16.30-128	4.2	b	93.6	ab	176.0	b	343.1	b	155.6	ab	772.4	b	24.0	b

[z]Mean fruit weight was determined by dividing total marketable fruit yield per plot by total marketable fruit number per plot.

[y]Mean separation within columns is by Tukey's HSD test, $P \leq 0.05$.

Table 2. Trained sensory panel ratings (0 to 10 linear scale, with increasing intensity) for 'Florida Brilliance', 'Florida127' and FL 16.30-128 on seven harvests over two seasons.

Cultivar	Firmness	Sweetness	Sourness	Strawberry flavor	Green/unripe flavor
		January 2019 (n[z] = 8)			
FL Brilliance	5.9 a[y]	4.7 b	5.1 a	3.7 b	2.0 a
Florida127	5.4 ab	4.3 b	4.3 a	4.2 a	1.8 a
FL 16.30-128	4.6 b	5.7 a	4.9 a	5.1 a	1.4 a
		February 2019 (n = 9)			
FL Brilliance	5.5 a	3.4 b	5.4 a	3.7 b	2.1 a
Florida127	4.9 a	4.9 a	3.9 b	4.5 b	1.7 a
FL 16.30-128	5.8 a	5.3 a	4.9 ab	5.1 a	1.4 a
		March 2019 (n = 8)			
FL Brilliance	6.8 a	3.5 a	5.4 a	3.0 b	2.2 a
Florida127	5.6 b	4.3 a	5.6 a	4.0 a	1.8 ab
FL 16.30-128	5.7 b	4.5 a	5.0 a	4.1 a	1.2 b
		December 2019 (n = 9)			
FL Brilliance	6.7 a	3.9 b	5.3 a	3.8 b	2.5 a
Florida127	5.4 b	4.9 a	4.8 a	5.5 a	1.6 b
FL 16.30-128	3.9 c	5.7 a	5.7 a	5.8 a	1.6 b
		January 2020 (n = 9)			
FL Brilliance	4.5 a	5.5 a	3.3 a	4.7 a	1.0 a
Florida127	4.1 a	5.8 a	3.8 a	4.8 a	1.4 a
FL 16.30-128	4.2 a	5.9 a	3.9 a	5.1 a	0.8 a
		February 2020 (n = 10)			
FL Brilliance	4.5 a	4.1 a	5.0 a	3.8 a	1.3 a
Florida127	4.3 a	4.7 a	4.7 a	4.2 a	1.1 a
FL 16.30-128	4.6 a	5.0 a	5.4 a	4.2 a	1.0 a
		March 2020 (n = 9)			
FL Brilliance	6.3 a	4.7 a	4.6 a	4.0 a	1.1 a
Florida127	4.6 b	4.8 a	3.9 a	4.3 a	1.2 a
FL 16.30-128	5.4 ab	5.8 a	5.2 a	5.1 a	0.7 a

[z]Number of trained panelists

[y]Mean separations within harvest dates and columns are by Tukey's HSD test, $P \leq 0.05$.

DNA Test Development – collaborators include Dr. Nahla Bassil, USDA-ARS, Corvallis, OR and Dr. Steven J. Knapp, UC-Davis, Davis, CA.

Impact Statement: An increasing number of DNA tests are being developed, published, and made available to the strawberry breeding and genetics community.

A strawberry DNA testing handbook has been developed and made available on GDR. Please use the following link (https://www.rosaceae.org/organism/Fragaria/x-ananassa?pane=resource-4) and click on the handbook at the bottom. It will be continually updated as new DNA tests are developed. Many of these tests have been developed and shared via multi-institutional collaborations, including Dr. Nahla Bassil, USDA-ARS, Corvallis, OR and Dr. Steven J. Knapp, UC-Davis, Davis, CA.

Genomic Selection Methodology Development – collaborators include Dr. Rex Bernardo, University of Minnesota, St. Paul, MN and Dr. Patricio Munoz, UF Horticultural Science, Gainesville, FL.

Impact Statement: The impacts of the RosBREED consortium continue to be felt across many Rosaceae breeding programs, including the strawberry breeding program at UF. We continue to conduct research into effective applications of genomic prediction in strawberry parent and seedling selection, continuing the work that began during RosBREED.

Please see Gezan et al., 2017 and Zingaretti et al., 2020 below under publications. We also have an accepted publication in Frontiers in Plant Science on the use of genomic prediction over multiple breeding cycles, Osorio et al. that will hopefully be available soon.

Recent Selected Publications

Barbey, C.R., M. Hogshead, A.E. Schwartz, N. Mourad, S. Verma, S. Lee, V.M. Whitaker and K.M. Folta. 2020. The genetics of differential gene expression related to fruit traits in strawberry. Frontiers in Genetics 10:1317.

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Mangandi, J., S. Verma, L.F. Osorio, N.A. Peres, E. van de Weg and V.M. Whitaker. 2017. Pedigree-based analysis in a multiparental population of octoploid strawberry reveals QTL alleles conferring resistance to *Phytophthora cactorum*. G3:Genes, Genomes, Genetics 7:1707-1719.

Gezan, S., L.F. Osorio, S. Verma and V.M. Whitaker. 2017. An experimental validation of genomic selection in octoploid strawberry. Horticulture Research 4:16070.

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IOWA STATE UNIVERSITY

NCCC-212 Report, October 2020

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Updates:

Tenure-track faculty position in fruit crops.

Constraints imposed on Iowa State University as a result of the global pandemic have caused the search and hiring of a tenure-track fruit crops specialist in the Department of Horticulture to be temporarily postponed. This position will be advertised with the majority of the appointment in Extension and outreach. With the permission of the Dean of the College of Agriculture & Life Sciences, the Department of Horticulture hopes to advertise for this position sometime in 2021. Any inquiries may be directed to Dr. Jeff Iles, Chair and Professor, Department of Horticulture (iles@iastate.edu).

New faculty member in enology.

Dr. Aude Watrelot was hired as Assistant Professor of Enology in the Department of Food Science and Human Nutrition () in August 2019, with activities in the Midwest Grape and Winery Industry Institute.

2020 Derecho in Iowa and the Midwest.

An extraordinary weather event happened on August 10, 2020 – a derecho blew across middle Iowa creating significant destruction. Derecho is a weather term used to denote widespread, straight-line winds and is Spanish for “direct”, “straight ahead”. The 2020 derecho had strong winds ranging from 80 to 140 mph and were ongoing for 40 to 50 minutes in a location; the sustained winds differed from a typical derecho, when winds last for 10 to 20 minutes. Appendix pages have a few photographs showing the event from the National Weather Service and the damage at the Iowa State University Horticulture Research Station’s vineyards. Vineyards have been rebuilt.

COVID-19 and outreach activities.

Due to the COVID-19 global pandemic, Iowa field days in person in 2020 were cancelled. Some virtual field days were held.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Validation of a Florida warning system to control strawberry anthracnose fruit rot, *Colletotrichum acutatum*, for less reliance on fungicide sprays by Midwest strawberry growers.

Evaluation of viticultural practices for 'Marquette' and ' La Crescent' grapevines grown in single- or double-cordon training systems.

Publications – NCCC-212 Objectives 1 and 2:

Strawberry:

Zhang, X., Batzer, J.C., Peres, N.A., and Gleason, M.L. 2019. Validation of a Florida strawberry anthracnose fruit rot warning system in Iowa. Plant Disease. 103:28-33. doi: https://doi.org/10.1094/PDIS-11-17-1762-RE

Grape:

Nonnecke G. R. and J. Schrader. 2020. Impact of minimum winter temperatures on the growth of winegrape cultivars and advanced selections. Iowa State University Research and Demonstration Farms Progress Reports 2019-36, p. 23-24. RFR-A1928: Available online: https://www.iastatedigitalpress.com/farmreports/article/id/11321/

Schrader, J.A., D.R. Cochran, P.A. Domoto, and G.R. Nonnecke. 2020. Yield and berry composition of cold-climate grape cultivars and advanced selections in Iowa climate. HortTechnology. 30(2):193-203. doi: https://doi.org/10.21273/HORTTECH04557-19

Schrader, J.A. D.R. Cochran, P.A. Domoto, and G.R. Nonnecke. 2019 (Dec.). Phenology and Winter Hardiness of Cold-climate Grape Cultivars and Advanced Selections in Iowa Climate. HortTechnology. 29(6):906-922. doi: https://doi.org/10.21273/HORTTECH04475-19

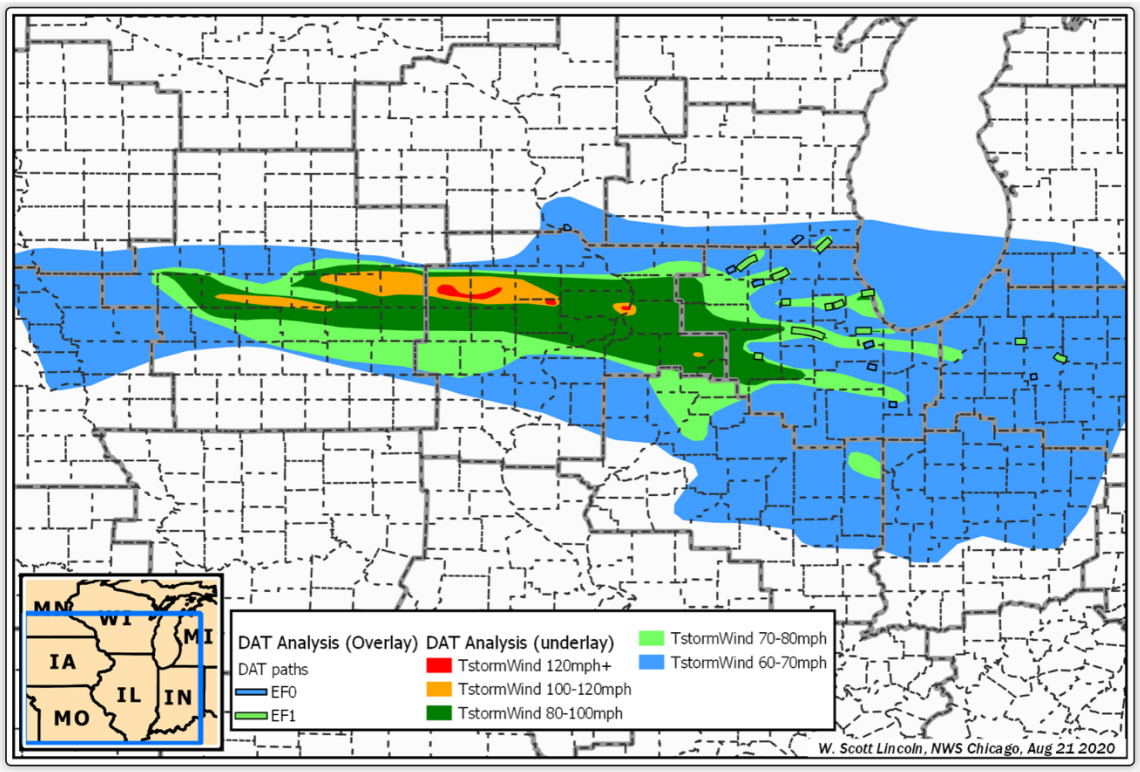
Ghuffar, S., G. Irshad, A.S. Gondal, R. Ahmad, H. Rosli, X. Zhang, H.M.U. Aslam, M.A. Iqbal, and M.L. Gleason. 2019. First report of *Rhizopus stolonifer* causing Rhizopus bunch rot of grapes in Pakistan. International Journal of Phytopathology. 8:29-30. Available online: https://esciencepress.net/journals/index.php/phytopath/article/view/2776

Watrelot A.A. and E. Norton. 2020. Chemistry and reactivity of tannins in *Vitis* spp.: A Review. Molecules. 25(9):2110. doi: 10.3390/molecules25092110

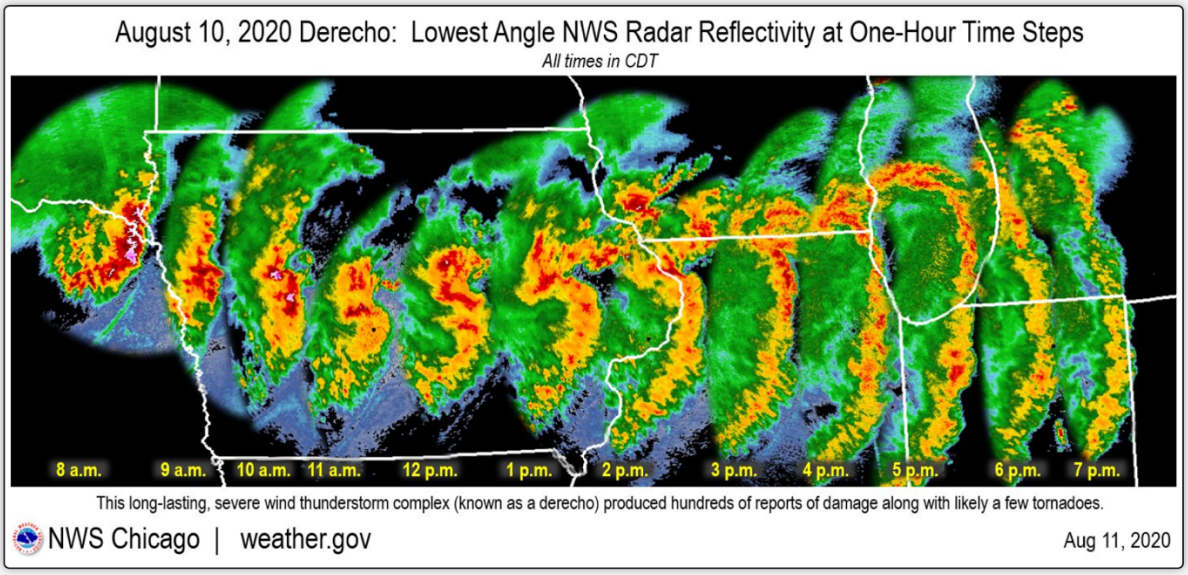
Appendix

A. Derecho images from the National Weather Service, August 10, 2020: https://www.weather.gov/dmx/2020derecho
B. Photographs of the ISU Horticulture Research Station's vineyards.

Appendix A: National Weather Service, August 10, 2020.



Preliminary map above shows the estimated wind speeds of the August 10, 2020 derecho across the region as of August 21, 2020. This is a collaborative effort between weather forecast offices Des Moines, IA Sioux Falls, SD Omaha, NE, Quad Cities, IA/IL, La Crosse, WI, Milwaukee, WI, Chicago, IL, central Illinois, IL, northern Indiana, IN, Indianapolis, IN, northern Indiana, IN, and Grand Rapids, MI. Thanks to Scott Lincoln, WFO Chicago for working with numerous offices to gather and refine this regional map.



Hourly radar images of the derecho's progression across the region. Image courtesy NWS Chicago (original).

Appendix B. Iowa State University, Horticulture Research Station's Vineyards.

August 12, 2020. Derecho damage to vineyard trellises.

October 12, 2020. Replacement of damaged vineyard posts and trellis system.

NCCC-212 Small Fruit & Viticulture 2020 Report
University of Maine

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Objective 1.

2017-2019 Strawberry Variety Trial
A variety trail was established in the spring of 2017 at Highmoor Farm in Monmouth, ME. Thirteen varieties were planted and established as matted rows on narrow raised beds with four replications. Plots were 20 feet long and 22 inches wide with a single trickle irrigation line running beneath the beds. Yield and fruit quality data were collected in the spring of 2018 and 2019 (see table).

2020-2013 Small Fruit Variety Trials
New variety trials for matted row strawberries, hardy northern highbush blueberries and red raspberries are being established at Highmoor Farm in Monmouth, ME. This is part of a Maine Specialty Crop Block Grant *"Expanding Maine's Berry Industry to Improve Farm Profitability"*. The strawberry trial was planted in 2020 and is being established as narrow matted rows, with 13 varieties, replicated four times. The highbush blueberry trial was planted in 2020, with 12 varieties, replicated four times, using potted, two-year-old plants. The raspberry trial will be established in 2021 due to difficulties in obtaining plant stock.

Elderberry Variety Trial
An elderberry variety trial was planted at Highmoor Farm in Monmouth, Maine in the spring of 2019. Due to issues with planting stock, the plants were grown in pots for the 2018 season to improve uniformity. Drought conditions and deer browsing affected growth of the plants in 2020 During the spring of 2021, plants will be evaluated for winter hardiness, disease susceptibility, yield and fruit characteristics.

Grape Variety Demonstration Planting
Sixteen varieties of hardy table and wine grapes were planted in 2009 at Highmoor Farm in Monmouth, ME. Each cultivar is trained to both 4-arm kniffin and umbrella kniffin systems. To date, the *Lubrusca* types have generally been successful, with the exception of Canadice. Bluebell and Vanessa have performed very well. Among the *Vinifera* hybrids, St. Croix, M. Foch, Frontenac, Sabrevois and Marquette have performed well. Brianna and Alpenglow are also promising. Landott, Carot Noir and Noiret have had poor winter survival and have recently been replaced with L'Acadie Blanc, Itasca, Petite Pearl, and Adalmiina.

Objective 2.
2017 Prohexadion-calcium applications for matted row strawberries
Strawberry plants (Flavorfest) were established in a raised bed matted-row system in the spring of 2017. Following plant establishment two rates of Apogee were applied either once or twice, the latter three weeks apart (8/21, 9/11). Treatments were repeated following standard matted row renovation practices in August/September 2018 and 2019. Based on previous work with plasticulture systems, we hope to

determine the potential for prohexadione-calcium as a method to manipulate vegetative growth; specifically, to reduce runners and increase branch crowns. Data from the trial is being analyzed.

Strawberry Integrated Pest Management Program: We monitor 10 commercial strawberry sites in southern and mid-state Maine for strawberry pests from April-June. We publish a weekly newsletter and blog regarding the pest situation in local strawberry fields during the pre-harvest season.
Impacts: Recent program evaluations by growers indicate that nearly all participants have reduced pesticide applications (83%) and costs (100%) as a result of the program. Additionally, growers now time sprays in response to pest monitoring results, and most have adopted at least one non-chemical alternative pest management strategy.

Tarnished Plant Bug Parasitism Survey
Tarnished plant bug pressure in strawberries has appeared to decline over the past three decades in the northeastern United States, thought to be due to the introduction of a parasite, *Peristenus digoneutis*. However, in recent years populations of this pest and its damage, seem to be increasing. In 2021, we will begin surveying TPB nymphs in Maine to determine the current level of parasitism in the population. This survey will be carried out in cooperation with the Maine department of Agriculture, Forestry and Conservation and USDA-APHIS.

Spotted-Wing Drosophila We monitored nine commercial small fruit sites in southern and central Maine this season for spotted wing drosophila, using vinegar/flour/yeast-baited traps. Information on SWD populations and management recommendations were passed on to growers throughout the state through a weekly electronic newsletter and blog (https://extension.umaine.edu/highmoor/blog/tag/spotted-wing-drosophila/).
Impacts: over 200 Maine growers receive the spotted wing drosophila updates. Program surveys found that most growers now aware of this pest and, use this program, to access to management information.

Other Publications:

Wild Blueberry Research & Extension
The University of Maine has an extensive research and Extension program for wild blueberries (*Vaccinium angustifolium*), most recently concentrating on pest management, pollination and food safety. For any members interested in seeing the latest project reports, They are available as pdf files. You can contact me (david.handley@maine.edu) or Lily Calderwood, Wild Blueberry Specialist (lily.calderwood@maine.edu) for a copy.

Strawberry Variety Trial 2018-2019
Highmoor Farm, University of Maine

Variety	2018 Kg/Plot	2019 Kg/Plot	Fruit Size (g)[1]	Season	Comments
Wendy	4.8	6.0	10.4	Early	Productive, attractive, good flavor
Archer	3.6	1.7	14.3	Early	Good size & appearance, good flavor, winter injury
Galletta	3.1	4.9	13.8	Early	Good size & appearance, uniform
Lila	7.0	6.3	10.4	Early-mid	Large, attractive, good flavor. Red steles res.
Flavorfest	5.7	2.8	10.2	Early-mid	Large, attractive, good flavor. Red steles res.
Yambu	7.9	10.3	11.1	Early-mid	Large, attractive, firm, variable flavor
Rutgers Scarlet	2.7	3.0	10.3	Midseason	Attractive, good flavor, low yields
Jewel	12.6	8.3	10.0	Midseason	Good size, attractive, glossy, firm
Laurel	11.6	8.9	8.4	Midseason	Attractive fruit, not large Red stele res.
Cabot	7.5	2.5	18.3	Mid-late	V. large fruit, many misshapen, good flavor
Mayflower	8.1	6.6	9.9	Mid-late	Large fruit; size falls fast. Light, dull color, tart
Valley Sunset	5.6	3.2	15.4	Late	Large, attractive fruit, good flavor, winter injury
Malwina	3.5	1.2	13.3	V. late	Dark color, very firm, good flavor, winter injury

Plots 20’ long x 1.5’ wide raised bed matted rows, planted 2017. Each variety replicated four times.
[1]Average fruit size over entire harvest season

Michigan State University
Report to NCCC-212, November 2020

ANNOUNCEMENTS:

1. New collaborators needed! If you have access to galls from the blueberry stem gall wasp and interested in collaborating with us, please contact Pat Edger (edgerpat@msu.edu). Additional information regarding this insect pest can be found here: https://www.canr.msu.edu/news/blueberry_gall_wasp_management_guidelines

OBJECTIVE I – DEVELOP IMPROVED FRUIT GERMPLASM THROUGH COOPERATIVE BREEDING

Blueberry: Molecular breeding efforts in blueberry have been slow due in large part to the lack of genetic information and genomic resources. Previous studies have developed genetic and genomic resources for a wild diploid species (2*n*=2*x*=24) of blueberry (Gupta et al., 2015). However, this draft genome has a large number of scaffolds (13,757 total; N50 of ~145kb), high percentage of gaps (~27.35%) in ~393.16Mb assembly, and most importantly, does not reflect the genome complexity of the economically important and tetraploid (2*n*=4*x*=48) highbush blueberry. Last year, we published a chromosome-scale genome for the tetraploid northern highbush blueberry (Colle et al., 2019). The haplotype-phased assembly consists of 48 chromosome-length pseudomolecules with 1,679,081,592 bases of assembled sequence, ~1.29% gaps, and an average of 32,140 protein coding genes per haplotype (128,559 total). Benchmarking Universal Single-Copy Orthologs (BUSCO) analysis was performed to assess the completeness of the assembly and quality of the genome annotation. The annotated gene set contains 1,413 out of 1,440 (98%) BUSCO genes. The availability of this draft genome will facilitate the discovery and analysis of genes encoding economically important traits and accelerate genome-guided breeding efforts. We leveraged this genome, combined with gene expression and metabolite data measured across fruit development, to identify candidate genes involved in the biosynthesis of important phytonutrients among other metabolites associated with superior fruit quality.

Genomic resources for blueberry are publicly available: Dataset and Genome Browser.

Current work: As part of a USDA SCRI project (VacCAP; https://www.vacciniumcap.org/), we are currently assembling a pangenome for Northern Highbush (NHB), Southern Highbush (SHB), and cranberry (CB). For each crop, 12 genotypes that are highly representative of the pedigree of NHB, SHB and CB cultivars and that capture the greatest amount of genetic diversity were selected. Our preliminary data suggests that roughly 30% of genes are unique to individual blueberry cultivars, due to gene duplication and loss patterns across the genome. Pangenome analyses will be conducted to identify the variable gene content that contributes to fruit quality differences between various cultivars. A Vaccinium genotyping platform will be developed that will target both the core (80%) and dispensable (20%) portions of the pangenome for NHB, SHB and CB.

Strawberry: A high-quality reference genome for the octoploid to serve as a platform for identifying agriculturally important genes and applying genomic-enabled breeding approaches. The assembly of the octoploid strawberry genome, with an estimated genome size of 813.4 Mb, has been particularly challenging due to its high heterozygosity and ploidy level. We recently published a chromosome-scale genome for the cultivated octoploid strawberry (*Fragaria* x *ananassa*) (Edger et al., 2019). The total length of the final assembly is 805.5Mb distributed across 28 chromosome-level pseudomolecules, plus 408.2Mb of haplotype variants. We annotated 108,087 protein-coding genes along with 30,703 long non-coding RNA (lncRNA) genes. Gene annotation and genome assembly quality were evaluated using the Benchmarking Universal Single-Copy Orthologs (BUSCO) method. Most (99.17%) of the 1,440 core genes were identified in the annotation, supporting a high-quality genome assembly and annotation. Furthermore, we identified genes that encode various important traits, including metabolites associated with fruit quality and disease-resistance.

Genomic resources for octoploid strawberry are publicly available: Dataset and Genome Browser.

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We previously also published a near-complete genome of diploid woodland strawberry (*Fragaria vesca*) (Edger et al., 2018). This genome assembly (220.8 Mb total) has a contig N50 length of ~7.9 million base pairs (Mb), representing a ~300-fold improvement of the previous version. The vast majority (>99.8%) of the assembly was anchored to 7 pseudomolecules. We obtained ~24.96 Mb of sequence not present in the previous version of the *Fragaria vesca* genome and produced an improved annotation that includes 1496 new genes. Genomic analyses uncovered numerous, large-scale scaffolding errors present in each chromosome in the previously published version of the *F. vesca* genome. This new version of the genome has already been leveraged to identify resistance locus to Fusarium wilt in octoploid strawberry (Pincot et al., 2018).

Genomic resources for diploid *F. vesca* are publicly available: Dataset and Genome Browser.

We also recently published a chromosome-scale genome for another diploid progenitor (*Fragaria iinumae*) of the cultivated strawberry (Edger et al., 2020).

Genomic resources for diploid *F. iinumae* are publicly available: Dataset and Genome Browser.

Lastly, using these new genomic resources, two new genotyping arrays (850K and 50K) have been developed for strawberry – please see (Hardigan et al., 2020) for details.

Collaborative Projects with NCCC-212 Members

"VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes" was funded by NIFA-SCRI from 2019-2024. The project involves multiple NCCC-212 committee members.

References:

1. Colle, M., C.P. Leisner, C.M. Wai, S. Ou, K.A. Bird, J. Wang, J.H. Wisecaver, A.E. Yocca, E.I. Alger, H. Tang, Z. Xiong, P. Callow, G. Ben-Zvi, A. Brodt, K. Baruch, T. Swale, L. Shiue, G. Song, K.L. Childs, A. Schilmiller, N. Vorsa, C.R. Buell, R. VanBuren, N. Jiang, and P.P. Edger. 2019. Haplotype-phased genome and evolution of phytonutrient pathways of tetraploid blueberry. GigaScience 8(3), giz012.

2. Edger, P.P., T.J. Poorten, R. VanBuren, M.A. Hardigan, M. Colle, M.R. McKain, R.D. Smith, S.J. Teresi, A.D.L. Nelson, C.M. Wai, E.I. Alger, K.A. Bird, A.E. Yocca, N. Pumplin, S. Ou, G. Ben-Zvi, A. Brodt, K. Baruch, T. Swale, L. Shiue, C.B. Acharya, G.S. Cole, J.P. Mower, K.L. Childs, N. Jiang, E. Lyons, M. Freeling, J.R. Puzey, and S.J. Knapp. 2019. Origin and evolution of the octoploid strawberry genome. Nature Genetics 51(3), 541.

3. Edger, P.P., R. VanBuren, M. Colle, T.J. Poorten, C.M. Wai, C.E. Niederhuth, E.I. Alger, S. Ou, C.B. Acharya, J. Wang, P. Callow, M.R. McKain, J. Shi, C. Collier, Z. Xiong, J.P. Mower, J.P. Slovin, T. Hytonen, N. Jiang, K.L. Childs, and S.J. Knapp. 2018. Single-molecule sequencing and optical mapping yields an improved genome of woodland strawberry (*Fragaria vesca*) with chromosome-scale contiguity. *GigaScience* 7(2), gix124.

4. Patrick P Edger, Michael R McKain, Alan E Yocca, Steven J Knapp, Qin Qiao, Ticao Zhang. 2020. Reply to: Revisiting the origin of octoploid strawberry. Nature Genetics 52 (1), 5-7.

5. Pincot, D.D.A., T.J. Poorten, M.A. Hardigan, J.M. Harshman, C.B. Acharya, G.S. Cole, T.R. Gordon, M. Stueven, P.P. Edger, and S.J. Knapp. 2018. Genome-Wide Association Mapping Uncovers Fw1, a Dominant Gene Conferring Resistance to Fusarium Wilt in Strawberry. *G3: Genes, Genomes, Genetics.* 8(10), 1817.

6. Michael A Hardigan, Mitchell J Feldmann, Anne Lorant, Kevin A Bird, Randi Famula, Charlotte Acharya, Glenn Cole, Patrick P Edger, Steven J Knapp. 2020. Genome synteny has been conserved among the octoploid progenitors of cultivated strawberry over millions of years of evolution. Frontiers in Plant Science 10, 1789.

MISSISSIPPI STATE UNIVERSITY

List your research and extension projects under the official NCCC 212 objectives, emphasizing collaborative projects with other researchers. A suggested format is below.

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Creating interspecific hybrids among Passiflora species to encourage fruit production in subtropical growing regions. E. Stafne, Mississippi State University; A. Chambers, University of Florida.

Small-scale, minimal management breeding of Pierce's disease tolerant and resistant grapes and muscadines. E. Stafne

Evaluation of thornless blackberry seedlings for potential in Gulf South growing conditions. E. Stafne

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Evaluating blackberry cultivars for tolerance to white drupelet disorder. E. Stafne, Mississippi State University; Barbara J. Smith, USDA-ARS Poplarville

Renovation pruning of blueberry cultivars in Mississippi. E. Stafne, MSU; B.J. Smith, USDA-ARS

List retrievable or archived publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications. Please use ASHS style.

Ryals, J.B., P.R. Knight, and E.T. Stafne. 2020. Rooting response of seven passion fruit species to basal application of auxin. HortTechnology https://journals.ashs.org/horttech/view/journals/horttech/aop/article-10.21273-HORTTECH04660-20/article-10.21273-HORTTECH04660-20.xml.

Mavrodi, O.V., D.V. Mavrodi, E.T. Stafne, John J. Adamczyk, Jr., and E.M. Babiker. 2020. Draft genome sequences of *Xylella fastidiosa* subsp. *fastidiosa* strains OK3, VB11, and

NOB1 isolated from bunch and muscadine grapes grown in southern Mississippi. Microbial Resource Announcement DOI: 10.1128/MRA.00562-20.

Stafne, E.T. 2020. #YardFruits: Twitter as a Tool to Disseminate Horticulture Education During A Pandemic. HortTechnology https://journals.ashs.org/horttech/view/journals/horttech/aop/article-10.21273-HORTTECH04717-20/article-10.21273-HORTTECH04717-20.xml

Stafne, E.T. and B.J. Smith. 2019. Effect of phosphorous acid and pruning height on renovated 'Woodard' rabbiteye blueberry. *In* Proceedings of the North American Blueberry Research and Extension Workers Conference. August 12-15, 2018, Orono, ME. 6 pp. University of Maine Digital Commons: https://digitalcommons.library.umaine.edu/cgi/viewcontent.cgi?article=1001&context=nabrew2018

Stafne, E.T. and B.L. Carroll. 2019. Simulated Abiotic Injury Alters Yields of Southern Interspecific Hybrid Grape Cultivars. Horticulturae 5(2):44 https://www.mdpi.com/2311-7524/5/2/44/htm

Abstracts

Stafne, E.T. and B.J. Smith. 2020. Higher Renovation Pruning Height Improves Early Yields of 'Woodard' Rabbiteye Blueberry. HortScience 55(9):S406. https://journals.ashs.org/hortsci/view/journals/hortsci/55/9S/article-pS1.xml

Stafne, E.T. and B.J. Smith. 2020. Additional Nitrogen Application May Reduce White Drupelet Disorder in 'Sweetie Pie' Blackberry. HortScience 55(9):S406. https://journals.ashs.org/hortsci/view/journals/hortsci/55/9S/article-pS1.xml

Smith, B.J., A. Rezazadeh, E.T. Stafne, and H. Sakhanokho. 2020. Effect of LED, UV-B, and fluorescent supplemental lights on plant growth and fruit quality of strawberries grown in a greenhouse and on their infection by *Colletotrichum* spp. HortScience 55(9):S232-233. https://journals.ashs.org/hortsci/view/journals/hortsci/55/9S/article-pS1.xml

Werle, C., O. Mavrodi, E.T. Stafne, E. Babiker, and J. Adamczyk. 2019. Resistance is not futile: Diversity and distribution of leafhoppers (Hemiptera: Cicadellidae) in Mississippi muscadines. ESA https://esa.confex.com/esa/2019/meetingapp.cgi/Paper/145366 (abstr.)

Extension Publications

Stafne, E.T. 2020. Fruit and Nut Review: Blackberries. MSU-ES 1444. (revision) http://extension.msstate.edu/publications/information-sheets/fruit-and-nut-review-blackberries

Oliver, J. et al. (eds.). 2020. Southeast Regional Caneberries Integrated Management Guide. Univ. Georgia Bull. 47 https://smallfruits.org/files/2020/01/2020-Caneberry-Spray-Guide.pdf (section editor)

Stafne, E.T. 2020. White Drupelet Disorder in Blackberries: Knowns and More Unknowns. Small Fruit News 20(3): https://smallfruits.org/category/small-fruit-news/.

Stafne, E.T. 2020. Some Vineyard Tasks to Prepare for Winter. Small Fruit News 20(4): https://smallfruits.org/2020/10/some-vineyard-tasks-to-prepare-for-winter/.

University of New Hampshire

1. List your research and extension projects under the official NCCC 212 objectives, emphasizing collaborative projects with other researchers.

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Strawberry:

Winter survival and second-year spring yields of day-neutral strawberry in the Northeast are influenced by cultivar and the presence of low tunnels. R.G. Sideman and K.M. Orde, University of NH, Durham NH

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Strawberry:

Advancing Strawberry Production in the Northeast. R.G. Sideman and K.M. Orde, University of NH, Durham NH; L. McDermott, Cornell Cooperative Extension, Hudson Falls NY; E Hodgdon, Cornell Cooperative Extension, Plattsburgh NY; D. Conner, University of VT, Burlington VT.

Photoselective film, mulch color, and low tunnel effects on the day-neutral strawberry cv. Albion. K. Orde and B. Sideman, University of NH, Durham NH; K. Demchak and R. Marini, Pennsylvania State University, State College, PA.

Grapes:

Yield and performance of eight seedless table grape cultivars grown in two training systems (Munson and VSP) in New Hampshire. NH Agricultural Expt. Station, Hatch Project NH00685. R.G. Sideman, M. Cogswell and K.M. Orde, University of NH, Durham NH; G. Hamilton, University of NH Extension, Goffstown NH.

Other small fruit crops:

Feasibility of in-ground production of fig in USDA hardiness zone5B using various winter protection strategies. NH Agricultural Expt. Station, Hatch Project NH00685. R.G. Sideman, University of NH, Durham NH.

Objective 3 - Explore the association between fruit constituents and human health impacts

Grapes:

Effects of cultivar and training system on human health-beneficial phytochemicals in seedless table grape. NH Agricultural Expt. Station, Hatch Project Acc. No. 1020314. M. Lima, A. Chandrakala, M.K .Hanlon, and R.G. Sideman, University of NH, Durham NH.

2. How have the results been disseminated to communities of interest?
What do you plan to do during the next reporting period to accomplish the goals?

During the reporting period, results have been disseminated to target audiences via 1) written extension newsletter articles, 2) virtual twilight meetings, 3) presentations at grower conferences and inservices, 4) promotion through social media, and 5) farm tours/field days.

Strawberry: We will initiate experiments designed to test the following hypotheses: the use of heavier weight rowcover will increase winter survival of strawberries, and earlier fall application of rowcover will increase yields of June-bearing strawberry the following year.

Grape: In 2021, we will add seven newly-released table grape varieties to the vineyard to evaluate performance (hardiness, yield, susceptibility of diseases, etc.) in our region, and will continue to collaborate with M. Lima (see her Hatch Accession No. 1020314 for details), using mature vines of 'Mars' and 'Canadice'.

Fig: We will continue to collaborate with stakeholders to assess both crop quality and market potential of fresh fig growing in minimally protected environments. Established plantings will be protected for a second winter using the same experimental design as was used in the first winter. In 2021, we will assess winter survival and timing and quantity of fruit production.

3. Include any data, gemplasm/cultivar descriptions, research results, etc. that you would like to discuss at the meeting. Please keep this brief, highlighting no more than three discussion points within 500 words. Additional information (data tables, abstracts, etc…) can be included in an appendix.

Strawberry: Building upon the USDA-AFRI SCRI project 'Optimizing protected culture environments for berry crops', e.g. TunnelBerries, we compared the performance of several dayneutral strawberry cultivars in NH in a two-year study. While typically grown as annuals that are harvested for one fall season only, many growers in our region hold these plantings and obtain a spring crop as well. We observed that both cultivar AND the use of low tunnels influenced winter survival and fall as well as spring yields of dayneutral strawberry. For some cultivars, winter survival was consistently high, and spring yields even exceeded first-year fall production in some cases.

Grape: In 2015, we established a research vineyard containing eight seedless table grape cultivars using two training systems: vertical-shoot positioning (VSP) and Munson (M). During the past five years, we assessed vine vigor and incidence of diseases and insect pests, and collected yield data. We have observed significant differences among varieties in incidence of powdery mildew, downy mildew, and anthracnose, as well as in fruit yield and quality. We found that the VSP training system reached harvest maturity at least one year earlier than the other systems, thus increasing early yield potential; but vines trained to the MM system have produced higher annual yields once established. In the past year, we have begun to collaborate with other researchers to expand research objectives to include assessment of nutritional phytochemicals.

Fig: We have just begun to study systems of winter protection of figs grown in-ground, and to investigate the effects of different protection strategies on growth and fruiting patterns for four fig cultivars: Violette de Bordeaux, St. Rita, J.H. Adriatic, and Takoma Violet. In Winter 2019-2020, we measured the effects of different winter protection systems (winter blankets, heavy rowcover, leaves, low tunnels, and high tunnels) on overwinter survival and subsequent plant growth and fruit set for several fig cultivars. We observed significant effects of protection system (but not cultivar) on winter survival, and significant effects of both production system AND cultivar on fruit set and timing of fruit ripening. We continue to collect data and will publish a preliminary research report in Winter 2021.

4. List retrievable or archived publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications. Please use ASHS style.

Orde KM and RG Sideman. 2020. Winter survival and second-year spring yields of day-neutral strawberry in the Northeast are influenced by cultivar and the presence of low tunnels. *Accepted for publication, HortTechnology*.

Orde KM and RG Sideman. 2019. Low tunnel and cultivar effects on day-neutral strawberry yield and characteristics in New Hampshire. HortTechnology *29(6): 795-810.*

Lima M, RG Sideman, A Chandrakala, and MK Hanlon. 2020. From harvest to consumer: Are grape's health-beneficial properties modified with time in storage? Nutrition 2020 Conference. June, 2020.

Sideman RG. 2020. Extension Research Report: Seedless table grape variety & training system evaluation, 2019. Sideman RG. Available at: <https://extension.unh.edu/resources/files/Resource007159_Rep10342.pdf>

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NCCC 212 State Report for New Jersey 2020
Submitted by:
Edward Durner
Associate Research Professor

1. **NJAES Project 12159**
Alternative Small Fruit Production Strategies
Edward Durner, Rutgers- The State University of New Jersey

Goldenberry (*Physalis peruviana*)
Strawberry

Accomplishments and plans are presented below for each specific project included in this umbrella NJAES project.

Publications for all projects:

Refereed:

Durner, E.F., 2020. Growth of 'Seascape' strawberry (Fragaria X ananassa Duch.) is altered by photoperiod and nitrogen conditioning. The Journal of Horticultural Science and Biotechnology, DOI: 10.1080/14620316.2020.1719906.

Durner, E.F., 2019. Effective Analysis of Interactive Effects with Non-Normal Data Using the Aligned Rank Transform, ARTool and SAS® University Edition. Horticulturae 5(3): 57 – 69 https://doi.org/10.3390/horticulturae5030057

Durner, E.F., 2019. Responses to nitrogen conditioning in 'Albion' strawberry (Fragaria X ananassa Duch.) for off-season plasticulture production are primarily qualitative rather than quantitative. Scientia Horticulturae, 257 https://doi.org/10.1016/j.scienta.2019.108684 , published online 18 July 2019.

Non-refereed:

Durner, E.F. 2020. Growing Goldenberries. Proceedings of the 2020 New Jersey Agricultural Convention and Trade Show (NJ ACTS) and New Jersey Vegetable Growers Meeting. Harrah;s Resort Hotel Convention Center, Atlantic City, New Jersey.

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Durner, E.F. 2020. Enhancing Fall "Albion" Strawberry Production. Proceedings of the 2020 New Jersey Agricultural Convention and Trade Show (NJ ACTS) and New Jersey Vegetable Growers Meeting. Harrah;s Resort Hotel Convention Center, Atlantic City, New Jersey.

Durner, E.F. 2020. Enhancing Fall 'Albion' Strawberry Production with Inexpensive Field Lighting_Does It Really Work? Proceedings of the 2020 Mid-Atlantic Fruit and Vegetable Convention, Hershey, Pennsylvania.

Durner, E.F. 2019. Fall Strawberries and Goldenberries: Alternative Annual Fruits for New Jersey Growers. Proceedings of the 2019 New Jersey Agricultural Convention and Trade Show (NJ ACTS) and New Jersey Vegetable Growers Meeting. Harrah;s Resort Hotel Convention Center, Atlantic City, New Jersey.

Durner, E.F. 2019. Goldenberries: A New Superfruit for North America. Proceedings of the 2019 Mid-Atlantic Fruit and Vegetable Convention, Hershey, Pennsylvania.

Durner, E.F. 2019. Strawberry Flower Mapping: Understanding Plant Development and Its Effect on Yield. Proceedings of the 2019 Mid-Atlantic Fruit and Vegetable Convention, Hershey, Pennsylvania.

Article in the American Fruit Grower, 19 April 2019 about this project. (https://fruitgrowersnews.com/article/goldenberry-new-superfruit-grows-in-us/)

Article in FreshPlaza newsletter, 7 May 2019 about this project. https://www.freshplaza.com/article/9101020/goldenberry-superfruit-can-be-grown-in-the-us/

Article in Acres magazine August 2019 about this project. https://www.ecofarmingdaily.com/grow-crops/growing-goldenberries-and-ground-cherries/

Presentations for all projects:

Durner, E.F. 2020. Enhancing Fall 'Albion' Strawberry Production With Holiday Light Strings. North Jersey Commercial Vegetable Growers Meeting, Flemington, NJ. February 26, 2020.

Durner, E.F. 2020. Growing Goldenberries. North Jersey Commercial Vegetable Growers Meeting, Flemington, NJ. February 26, 2020.

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Durner, E.F. 2020. Growing Goldenberries. 2020 New Jersey Agricultural Convention and Trade Show (NJ ACTS) and New Jersey Vegetable Growers Meeting. Harrah;s Resort Hotel Convention Center, Atlantic City, New Jersey, February 5, 2020.

Durner, E.F. 2020. Enhancing Fall "Albion" Strawberry Production. 2020 New Jersey Agricultural Convention and Trade Show (NJ ACTS) and New Jersey Vegetable Growers Meeting. Harrah;s Resort Hotel Convention Center, Atlantic City, New Jersey, February 5, 2020.

Durner, E.F. 2020. Enhancing Fall 'Albion' Strawberry Production with Inexpensive Field Lighting_Does It Really Work? 2020 Mid-Atlantic Fruit and Vegetable Convention, Hershey, Pennsylvania, January 30, 2020.

Durner, E.F. 2019. Strawberry Flowering Physiology and Things You Need To Know About It. Southeastern Strawberry Expo, Raleigh, NC, November 7, 2019.

Durner, E.F. 2019. Enhancing Fall Strawberry Production Using Inexpensive Light Strings. Southeastern Strawberry Expo, Raleigh, NC, November 8, 2019.

Durner, E.F. 2019. Fall Strawberries and Goldenberries: Alternative Annual Fruits for New Jersey Growers. 2019 New Jersey Agricultural Convention and Trade Show (NJ ACTS) and New Jersey Vegetable Growers Meeting. Harrah;s Resort Hotel Convention Center, Atlantic City, New Jersey, February 5, 2019.

Durner, E.F. 2019. Goldenberries: A New Superfruit for North America. 2019 Mid-Atlantic Fruit and Vegetable Convention, Hershey, Pennsylvania, January 31, 2019.

Durner, E.F. 2019. Strawberry Flower Mapping: Understanding Plant Development and Its Effect on Yield. 2019 Mid-Atlantic Fruit and Vegetable Convention, Hershey, Pennsylvania, January 31, 2019.

2. NJDA Specialty Crop Block Grant #AM180100XXXXG017
Summer and Fall Strawberry Production for NJ Using the Long-day Cultivar 'Albion'.
Edward Durner, Rutgers- The State University of New Jersey
Peter Nitzsche, Rutgers- The State University of New Jersey

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

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Strawberry

In 2019, experimental plantings of 'Albion' were established at two growers farms as well as at Rutgers Fruit and Ornamental Research Extension Center, Cream Ridge, to encourage the adoption of off-season strawberry production and marketing using a long day cultivar with supplemental field lighting. Severe deer pressure on one grower's farm and weed pressure at the other grower site resulted in lack of production on both farms. In addition, growers indicated that there was considerable difficulty establishing field lighting in their fields due to the distance from their electric source. There was also significant deer pressure at Cream Ridge, however, yield through September (prior to deer damage) from the Cream Ridge planting was on average 140 g/plant. At 15,000 plants per acre, this translates into ~4,600 lbs per acre. With an establishment cost of $10,315 per acre, Net income per acre through September would be $8085 at $4.00/lb and $12685 at $5/lb.

In 2020, plantings were established on two grower's farms as well as at Cream Ridge. Plugs were conditioned immediately after propagation and prior to field planting to avoid problems associated with field lighting. Netting was installed to prevent deer damage at Cream Ridge and one grower established plants in a greenhouse to avoid deer problems. Data will be collected through next spring for evaluation of this system.

3. Northeast Region SARE Project LNE18-362-32231
Goldenberries (Physalis peruviana) : A New Fruit for CSA Farms and Farmers Markets.
Edward Durner, Rutgers- The State University of New Jersey
Thomas Gianfagna, Rutgers- The State University of New Jersey
Thomas Molnar, Rutgers- The State University of New Jersey

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Goldenberry (*Physalis peruviana*)

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Goldenberry (*Physalis peruviana*)

Goldenberries are an underutilized, highly nutritious fruit that could prove to be easily incorporated in CSA farm production and farm market sales. This project is aimed at providing growers with a reliable alternative small fruit

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crop for inclusion in their standard vegetable rotation. This project includes the first systematic evaluation of *Physalis* germplasm to identify true goldenberry (*P. peruviana*), genotypes with characteristics that make them well-suited for commercial production. The project is also evaluating production systems utilizing white and black plastic mulch, trickle irrigation, and several training systems.

One hundred thirty five growers participated in on-farm goldenberry evaluation in 2019. As in 2018, thorough grower evaluation of the 'Schoenbrunn Gold' genotype was limited in that many growers again reported that they did not harvest ripe fruit. The major factor contributing to this lack of production is the long growing season required by goldenberry. This limitation will be addressed in 2021 via a high tunnel trial at Rutgers Fruit Research Center in Cream Ridge. Based on general e-mail interactions with growers, many of them enjoyed participating in this work. The lack of productivity has discouraged many of the participants. The number of fruit, average fruit weight and estimated potential yield per plant was assessed for 18 globally sourced genotypes in a study at Rutgers, Cream Ridge. No significant differences in yield were detected among the genotypes and productivity was greater in 2019 compared to the previous year.

Variability among goldenberry genotypes in 2019 was limited as in 2018. Again, two fruiting 'types' could be discerned among the 18 goldenberry lines evaluated: (1) genotypes producing smaller, marble sized and shaped fruit weighing approximately 2 -5 g each and (2) genotypes producing larger, more irregularly shaped fruit weighing 5 - 8 g each. The average number of fruit per plant ranged from 240 to 742 and smaller fruited genotypes generally tended to produce more fruit per plant compared to larger fruited genotypes. Yield per plant ranged from as low as 900 g per plant (~1.9 lb) to as high as 2200 g per plant (4.9 lbs per plant). Fruit size and estimated yields were much higher in 2019 compared to 2018 and closer to previous estimates from 2017. Larger fruited genotypes had a more fruit-like, tropical flavor compared to the smaller fruited genotypes which often had a background bitter flavor and the bitter flavor did not make the smaller fruited genotypes undesirable. The larger fruited genotypes received more favorable comments from informal taste tests than the smaller fruited genotypes with respect to desirability, similar to 2018. All genotypes were fairly consistently attractive with nice fruit shapes (round rather than irregular) and color (golden yellow/orange). The larger fruited genotypes sometimes had slightly irregularly shaped fruit, however, they were still attractive and nicely colored. Based on general observations over the two year test period, we recommend growing goldenberries on black plastic mulch, with a simple trellis and pruning plants until the first bifurcation of the main stem.

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A goldenberry fact sheet is available from:
https://projects.sare.org/information-product/goldenberry-fact-sheet/

4. Northeast Region SARE Project LNE20-395-34268
Empowering Northeastern Strawberry Growers with Flower Mapping
Edward Durner, Rutgers- The State University of New Jersey
Peter Nitzsche, Rutgers- The State University of New Jersey

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Strawberry

Current recommendations for fall nitrogen application and row cover management in annual strawberry plasticulture are based on tradition and calendar date. Decisions regarding both practices would be more appropriately based on the floral status of plants in production.

This project has two goals (1) to establish, document and demonstrate the clear relationship between floral status and productivity in strawberry and (2) to demonstrate that plant floral status can be modified with N and row cover manipulation based on floral maps. We will demonstrate the usefulness of floral mapping by demonstrating floral modification with pulsed N fertilization and appropriate row cover management.

Both goals are being addressed with one large integrated field study. Weekly flower maps and associated floral goals from propagation in July through harvest the following June are being developed for 2 cultivars in the annual plasticulture system. Modification of plant floral status via controlled N-pulse treatments and row cover manipulation will be assessed from September through December.

Research is being conducted at Rutgers Fruit and Ornamental Research Center in Cream Ridge, NJ and duplicated at The Clifford E. & Melda C. Snyder Research and Extension Farm - Rutgers Center for Sustainable Agriculture in Pittstown, NJ.

This project will also develop the procedural manual for flower mapping and provide suggestions regarding the use of data generated by flower mapping.

NCCC212 Report **Cornell University/New York State**

1. Research projects

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Effects of weather, farm location and management practices on flavor development in strawberry

We measured variation in total soluble solids (SSC), titratable acidity (TA), phenolic content, and aroma volatiles in fruit from a single cultivar (Jewel) across three years from up to 22 farms across New York State, and across nine different management practices on the same field site. Management practices varied in intensity and source of inputs. Our goal was to determine the relative contribution of weather, farm location and management practice to flavor variation. We hypothesized that SSC, TA, and the volatile profile would vary when grown at different sites and that management-induced variation in fruit quality would have measurable effects on sensory qualities when grown on the same site. However, we found that management practice was not associated with fruit quality traits; different levels of soil carbon inputs, N rates, and non-fertilizer inputs were not associated with variation in SSC, TA, volatile profile, or phenolic content. A human sensory evaluation found no perceptible differences in flavor or aroma of 'Jewel' grown under different management regimes. Yields were positively correlated with total N application in the form of urea, while organic N rate was not a significant predictor of yield. In contrast, quality attributes varied significantly from farm-to-farm, but year-to-year variation was even greater. Accumulated growing degree days (GDD,base 13.4˚C) from 1 April was sometimes weakly correlated with SSC and TA of fruit, but variation in aroma was not associated with local climate data. Our findings suggest that year-to-year variation in chemical composition is sufficiently large to affect sensory perception of flavor. Farm-to-farm variation in TA and SSC is smaller but still potentially detectable, but variation from differing management practices at the same location was not detectable by a human sensory panel nor by statistical analyses.

Low tunnel cover effects on day neutral strawberries

Standard low tunnels are typically covered with various plastics that vary in their light transmission properties. Some exclude U.V. radiation, some diffuse the light, etc. We are testing novel coverings against a standard plastic cover in an 'Albion' planting. The first novel covering is a fabric used as shade cloth in some greenhouse operations. It consists of strips of reflective material throughout a mesh fabric. The mesh size is large enough to not trap heat but small enough to exclude certain insect pests. Three fabrics are being tested that include

different densities of reflective strips. The purpose is to reduce the heat load under the fabric while simultaneously excluding insect pests. A second cover is manufactured in France and actually shifts wavelengths of light into the PAR range (https://www.lightcascade.com/en/applications/#). This pink plastic covering has shown potential in France under low light conditions. Our hypothesis is that plants will benefit from this covering later in the growing season.

2. Publications

1) Extension updates
    a. We are in the process of updating our berry diagnostic tool (https://blogs.cornell.edu/berrytool/)
    b. We have revised our high tunnel production guide for raspberries and blackberries (http://www.hort.cornell.edu/fruit/pdfs/high-tunnel-brambles.pdf)
    c. We wrote guidelines for PYO farms (https://smallfarms.cornell.edu/wp-content/uploads/2020/05/Cornell-U-Pick-Best-Practices-COVID-19.pdf) and agritourism (https://smallfarms.cornell.edu/wp-content/uploads/2020/09/Cornell-Agritoursim-BMPs-COVID.pdf) under COVID-19 conditions
    d. The Strawberry Production Guide for the Northeast is being revised

2) Refereed Publications:

Osatuke, A. and M. Pritts. 2021. Development of quality attributes in strawberry fruit: A review. J. Amer. Pomol. Soc., in press.

Stockton, D.G., Hesler, S., Wallingford, A.K., Leskey, T.C., McDermott, L., Elsensohn, J.E., Riggs, D. I., Pritts, M., Loeb, G.M. 2020. Factors affecting the implementation of exclusion netting to control *Drosophila suzukii* on primocane raspberry. Accepted for publication, 18 April 2020, *Crop Protection,* article ref no. JCRP_105191.

Pritts, M.P and T.M. Sjulin. 2019. Strawberries: A case study of how evolving market expectations impact sustainability. In: Lang, G. A. (ed.), Achieving sustainable cultivation of temperate zone tree fruits and berries Volume 2: Case studies, Burleigh Dodds Science Publishing, Cambridge, UK.

Gannett, M., M.P. Pritts and J. Lehmann. 2019. Soil amendments affect soil health indicators and crop yield in perennial strawberry. HortTechnology: 29: 179–188

NC STATE UNIVERSITY

NCCC-212 2020 Report

Prepared by members of the Department of Horticultural Science
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1. List your research and extension projects under the official NCCC-212 objectives, emphasizing collaborative projects with other researchers.

<u>Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:</u>

Blackberry and Raspberry:

***Rubus GWAS/BSH study,* Multi institution phenotyping project** initiated with Univ. Ark, Cornell, USDA-ARS Corvallis, BC Berry, Plant Science Inc (Watsonville) and Pairwise Plants (Durham NC) in 2019/2020. In spring and summer of 2020, . 5 cultivars were planted at each location and will be phenotyped over the next 2 years. Phenotyping has begun at most locations. New graduate student, Katie Sheehan-Lust (NCSU) will be using this project for her MS research. In addition, Pairwise plants, has developed five scaffold or pseudomolecule genome assemblies, generation genomic resequencing data for approximately 500 (?) public lines, and shared genomic resequencing data on all public lines and associated phenotype measurements in a publicly accessible database.

***Blueberry*:**

Characterized fruit quality traits in blueberry germplasm (Massimo Iorizzo in collaboration with Food Scientists and NCGR-OR). Extensive variation for all fruit traits (pH, TA, Brix/TSS, fruit size, anthocyanins, phenolic acids, flavanols, flavonols) evaluated in a Diversity Panel (DP) was detected. Broad sense heritability of the traits estimated in 100 tetraploid accessions, ranged from 20 to 90%, with most traits revealing moderate to high broad sense heritability (H2 > 40%), suggesting that strong genetic factors control these traits. TSS was positively and significantly correlated with most of the anthocyanins, flavanols, and phenolic aids and pH was positively associated with acylated anthocyanins. Fruit size can be estimated as a proxy of fruit weight or volume and vice versa, and it was negatively correlated with content of most of phytochemicals. However, size-independent variation for anthocyanin content and profile exists in the tetraploid accessions and can be explored to identify other factors such as genes related to the biosynthetic pathway that control this trait (Molla et al., 2020a, Farneti et al., 2020).

Establishing a community based project to advance fruit quality studies in blueberry and cranberry. (Massimo Iorizzo, Penelope Perkins-Veazie and Mary

Ann Lila from NCSU in collaboration with 17 blueberry and cranberry scientists). Secured a multimillion dollar (>6.4M) project, VacCAP, funded by USDA-NIFA (SCRI program) to develop marker assisted selection (MAS) capacity in *Vaccinium* breeding programs, to enable breeders to select and pyramid fruit characteristics (FCs) that positively contribute to fruit quality and market value. The project involves a multidisciplinary team of 20 scientists, from 13 US institutions including universities, USDA and two international institutions from New Zealand and Italy. Specific objectives are to: (1) establish a cost effective genotyping platform to expand marker-trait association analysis (MTA) in *Vaccinium*, exploiting the shared ancestry of *Vaccinium* crops; (2) identify DNA markers linked to fruit characteristics (FCs) and elucidate how and which fruit characteristics affect fruit quality, relative to consumer preferences, decay during mechanical harvest, processing and distribution; (3) develop DNA assays to implement MAS in core *Vaccinium* core breeding programs with a common focus on fruit quality traits; (4) enlarge market potential, and increase consumption of *Vaccinium* fruits by using socio-economic knowledge of consumer preferences to inform breeding; and (5) enhance sustainability of cultivar development by transferring MAS technologies to public and private U.S. Target fruit characteristics for blueberry include texture, size, scar diameter, volatile and non-volatile chemical composition. Fruit quality analysis will include, sensory analysis, shelf-life, bruising. The project began on Sept 1, 2019. During year 1 NCSU team performed phenotyping FCs in Northern Highbush material.

Ashrafi Blueberry Breeding and Genetics lab: Hamid Ashrafi, Jessica Spencer, Lauren Redpath, Rishi Aryal

Season overview: A cool Nov-Dec 2019 followed by unseasonal warmth in 2020 meant patchy flowering and unusual ripening behavior. The last hard frost in February took out Star, an early low-chill but everything else cropped ahead of normal time, with highbush season ending in late June and rabbiteye starting around the same time. A lot of intermittent heavy rains starting mid- season meant a lot of split and soft fruit and poor quality. Covid-19 prevented some analyses usually conducted indoors by multiple people, but overall the season proceeded normally.

Blueberry breeding efforts: The past 5 years have been rebuilding our traditional breeding program after faculty retirements left gap years.

Activity by Year	2015	2016	2017	2018	2019	2020
Crosses made	53	50	46	47	58	65
Seedlings transplanted to field		3700	4020	8000	9000	(8000)
Selections made	42	1	12	77	108	140
Cultivars & Selections put into Yield Trial	97	69	0	56	93	(80)
Selections Advanced			2	17	29	2
Cultivars & Selections put into Machine Harvest Trial			5		17	41
Selections put with growers/cooperators	2				2	(?)

An estimated 5,000 seedlings from 60 populations will be planted at the end of 2020, along with a high density plot with leftover seedlings from 2019 and/or 2020 modeled after University of Florida.

Selections are made mainly for commercial purposes, with selected bushes being scored on yield, firmness, scar, and flavor. Selections are cloned and put into yield trials of 4 plant plots in duplicate. A minimum of 2 bushes are harvested by hand. Total yield is recorded, and if possible, cup weight with count of good/tear/split/green, flavor, and firmness and size using Firmtech2. Selections are advanced based on these scores. 4-6 bushes of advanced selections are harvested and scored the same in following years but are also evaluated for soluble solids, titratable acids, pH, and storage-ability. Advanced selections are cloned via cuttings and tissue culture for on-site machine harvest trials (2 reps of 10 plants) and co-operator evaluation. After 2 years of yield trial data, we are at a point where we can begin more cooperator trials.

NC3104 has been disclosed with the NC State Office of Research Commercialization (ORC) and it is in process of patent processing. It is a sibling of New Hanover and very similar except without the stem-tears. It is a large, firm berry with good flavor, and blooms and ripens a few days after New Hanover and has a slightly darker color.

Efforts are disseminated in January at the NC Blueberry Council annual conference.

Cooperative efforts- After a few setbacks, we were able to send Michael Dossett in British Columbia, Canada softwood cuttings of Reveille x Arlen population of ~300 that have been central to marker studies at NCSU. We will likely need to repeat the process depending on survivability.

Blueberry Genetic Marker Development and Association Mapping

As part of AFRI project that was funded in 2019, entitled " Developing An Economic Standardized Genotyping Tool to Enhance Blueberry Breeding Programs" , PhD student Lauren Redpath, and research associate Rishi Aryal in collaboration with USDA-ARS scientists Dr. Nahla Bassil and her team at National Clonal Germplasm Repository and Dr. Amanda Haulse-Kemp team are working on a diversity panel of advanced selections and cultivars where native species have been hybridized into their pedigrees for trait introgression. As a part of this study 150 individuals at the Sandhills research station in Jackson Springs, NC and 76 individuals at the National Clonal Germplasm Repository were selected and phenotyped over the summers of 2019 and 2020 with 2 to 3 harvests per individual and clonal replication. Phenotyping included bloom time, fruit ripening duration and ting, as well as fruit skin color spectrum analysis, firmness, weight, size, area, anthocyanin content, puncturability, soluble solid and acid content determination, titratable acidity. Analysis confirmed that there were significant differences between successive harvests. Within a harvest there were significant differences between individuals for each of the measure traits; these results are anticipated in a diversity panel. Phenotypic measurements were highly correlated over the years of study ($R^2 >$ 0.55).

These phenotypic measurements are in the process of being associated with genotypic markers in a genome wide association study (GWAS). Sequence capture strategy via Tecan (Allegro) Targeted Genotyping) was used to capture 60,000 SNP makers in the gene space of blueberry. The markers were developed as part of the AFRI project as well

as a previous project by sequencing of ~54 blueberry accessions from 8 sections and 28 species. For the sequencing capture data, we used two pipelines for variant calling of 251 individuals including the individuals in the phenotyping population and select parents. We initially called 14.5 M variant positions with both Freebayes and an in-house pipeline, further filtering for previously established Allegro probes, we established 30,000 variant positions for further investigation. These probes have been used in STRUCTURE analysis, wherein patterns of introgressed species clustering has been detected, and GWASpoly for association analysis. Pseudo molecule development and scaffolding is underway to establish linkage groups and present a more accurate representation of association between variant and phenotype.

***Grape*:**

Muscadine anthocyanin grape profile shifted to more malvidin by using V. popenoi in crosses. Jim Ballington, Terry Bland, Guoying Ma, North Carolina State University. Malvidin is considered a more shelf stable anthocyanin pigment than the delphinidin most commonly found in muscadine grapes and products. Malvidin can be increased by using Fennels 3-way in crosses with V. rotundifolia. Ballington and Bland tested V. popenoi (DVIT 2970) as a parent to increase malvidin in V. rotundifolia. Fruit of 5 seedlings were screened for anthocyanin profiles for 2 years. Total anthocyanin content was high, at 1500-5900 mg/100g, and percent malvidin in the total anthocyanin content was increased from 10% to 50-80%.

***Strawberry*:**

Genome Wide Association Studies in an Octoploid Strawberry Biparental Population Discover QTLs for Hemibiotrophic and Necrotrophic Infection Resistance to Colletotrichum acutatum and C. gloeosporioides. Chacon, J.G., Olukolu, B., Iorrizo, M., Louws, F.J. & Fernandez, G. This study goals were to discover QTLs for the genetic resistance to the necrotrophic and hemibiotrophic stages of anthracnose diseases in octoploid strawberry. Using the new OmSeq platform, we found: 1. SNP's on multiple dosages in octoploid strawberry, 2. QTLs were discovered for resistance to anthracnose necrotrophic and HB infections. 3. Specific SNPs and subegenomic location determined (data not shown). Selection markers for future work. Linkage map and further exploration of QTL analysis underway.

Strawberry breeding. Fernandez, G, R. Schiavone, G. Chacon. Fruit from seedlings, selections and replicated trials were ripening during Covid-19 lockdown. Only one person allowed in the field for the first month. Limited data collected. However 5000 seedlings were evaluated and 122 new selections made. Focus of the program overall is on improving firmness, flavor, disease resistance and yield. 'Rocco' and 'Liz' doing well in the midwest. 'Rocco' replacing 'Sweet Charlie' as early season cultivar. 'Liz' is not good at producing runners and will be in low supply due to this trait.

Evaluation of composition, sugars, organic acid, and pigments in strawberry selections. Perkins-Veazie, Penelope and Gina Fernandez, NC State University

Cultivar evaluation and numbered breeding line evaluation in collaboration with Lassen Canyon and Cottle Farms. M. Hoffmann. Evaluation of yield and fruit quality

characteristics in an on-farm field trial. (partly funded by the NC Strawberry Association).

Impacts: 'Rocco' is gaining popularity in midwest states. Growers are replacing 'Sweet Charlie' with 'Rocco'. Estimated production for 2021 will be between 1.0 and 1.5 M plants.

Virtual Strawberry Field Day: more than 50 participants

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Blackberry and Raspberry:

Managing vigor of blackberry with prohexadione calcium: Effects on vegetative and reproductive development. Gina Fernandez, Tom Kon, Penny Perkins-Veazie and Karen Blaedow. Primocane growth management of blackberry by commercial growers relies on summer pruning/tipping primocanes at multiple heights throughout the growing season. However, tipping is a labor intensive and expensive process (~$600 per acre) that increases risk of cane blight infection. We investigated use of a plant growth regulator, prohexadione calcium (P-Ca), as an alternative primocane growth management strategy of blackberry. No treatments imposed in 2020 and no new data collected. Kon et al. received Specialty Crop Grant to support this work in 2021.

Survey of single and double cropped primocane fruiting blackberries at 2 on-farm locations. Objective was to assess seasonal nutrient status in single and double cropping primocane fruiting cultivars. We found: 1). Sufficiency survey levels do not follow those of floricane fruiting types, 2) most differences are evident between single and double cropped plants, 3) early season is not a good time for leaf sampling in sobule cropping systems, 4) June is stable for N and K, and 5) cultivars are different (so may need different recommendations). Fernandez, Hicks, Blaedow, Shires, Speer, McNicoll, and Gumpertz.

Pest Management Strategic Plan (PMSP) for Blackberry in Alabama, Arkansas, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Virginia. Gina Fernandez, Karen Blaedow, Hannah Burrack, Sara Villani, Katie Jennings, Wayne Mitchem, Danesha Seth-Carley, Daniel Tregeagle, Roger Batts, Rocco Schiavone, Katie Lohff, Phil Hatfield, Ryan Adams, North Carolina State University, Elizabeth Cieniewicz, Clemson University, Elina Coneva, Edgar Vinson, Arlie Powell, Auburn University, Katheryn Fontenot, Louisana State University, David Lockwood, University of Tennessee, Amanda McWhirt, University of Arkansas, Rebecca Melanson, Mississippi State University, Jonathan Oliver, University of Georgia, Doug Pfeiffer, Jayesh Samtani, Virginia Polytechnic Institute & State University (Virginia Tech), Guido Schnabel, Clemson University, Ash Sial, University of Georgia, Eric T. Stafne, Mississippi State University. In January 2020, thirty-one University Extension Specialists, IR-4 field research director and growers from the southern US met in Savannah, GA to develop this Pest Management Strategic Plan (PMSP) for blackberries. This PMSP is targeted for the states of Alabama, Arkansas, Georgia,

Louisiana, Mississippi, North Carolina, South Carolina, Tennessee and Virginia. These states are all members of the Southern Region Small Fruit Consortium.

Impacts: PMSP: Although blackberries are native to the southern region, and have been harvested for centuries, a significant commercial industry has developed in the past decade, valued between $100,000,000 and $250,000,000 (Tregeagle estimate). With the growth in commercial production, a number of challenges have emerged that can limit the productivity of this crop. The goal of this workshop was to develop a comprehensive list of pests (insect/mite, pathogen/nematode, weeds, and vertebrate/wildlife) and the known biological, chemical and cultural current control mechanisms for the pests. The attendees of the meeting developed lists of regulatory and research priorities in the following categories, cultural, insects/mites, weeds and diseases. Grower input was essential and with their help and guidance, we feel this report represents the current challenges and needs of the southern blackberry industry. The report will be submitted (and posted?) in December 2020. Sponsored by Southern IPM Center.

Blueberry:

Postharvest shelf life changes in blueberry cultivars Cooperators: Penelope Perkins-Veazie, Massimo Iorizzo, NCSU

Shelf Life: Cuticular Wax Bloom of Blueberry Fruit: An Innovated Edible Coating for Enhancing Quality and Shelf-life. Hamid Ashrafi, Mahnaz Kargar. North Carolina State University.

In summer 2020, we harvested ripe fruits of six different blueberry cultivars and accessions. The samples were stored in the walking cooler at 4°C to study the shelf life. Fruits of each cultivar/accession separated into two groups: with bloom, and without bloom (polished with cloth). Three replicates were considered for each group and 10 to 30 fruits were designated to each replication depending on the size of the fruits. Replicates were weighed every 10 days to investigate the weight loss during storage. They also were checked for rot and fungal deterioration during this time. The preliminary results show that the polished fruits had more weight loss compared to the unpolished ones which proves the role of bloom in water preservation and weight loss prevention. In addition, the number of rotted fruits observed in polished samples was higher than the samples with intact bloom.

***Grape*:**

Shelf Life of seedless and seeded muscadine grapes. M. Hoffmann and P. Perkins-Veazie. This work is supported by a NC New and Emerging Crops grant. Seedless muscadines have been introduced to the fresh market but little is known about their shelf life relative to seeded varieties. Evaluations are currently underway to follow changes in firmness, mold, browning during 0 to 42 days storage at 3 C.

Optimal pruning and flower removal studies on seedless muscadine cultivars. M. Hoffmann, E. Volk and P. Perkins-Veazie. Little is known about production and management of newly introduced muscadine cultivars. With different growth and flowering habits, pruning, trellising and management practices need to be explored

especially for the ever-bearing cultivar Razzmatazz. Evaluations are currently underway (ongoing, funded by the NCDA&CS NEC Program).

Grape Trunk Disease Management in NC.M. Hoffmann, E. Volk and S. Villani. Assessment of organisms involved in NC, development of best management practices and spray programs for NC, development of molecular assys for the PDIC, development of extension resources. (starting December 2020; funded by NC Grape and Wine Council; NCDA&CS Speciality Crop Grant).

Grapevine virus survey and development of testing service through the MPRU and PDIC. M.Hoffmann, C. Almeyda, W. Talton, M. AlRwahnih, M. Sudarshana, M. Nita, E. Volk: Ongoing, partly funded through the NC Grape and Wine Council.

Evaluation of seasonal differences in nutrient content of muscadine tissue samples M. Hoffmann, T. Rana (MHS thesis).

Impacts: Development of Grapevine Virus-Testing Service for North Carolina Growers in collaboration with PDIC; Securement of a trunk-disease management and identification block grant for North Carolina ($100,000). Several grape webinars on management, diseases, U-pick operations, reached more than 100 people; Agent training on grape cultural and pest management strategies in NC. Development of a muscadine production guide for the Southeast; COVID-19 related outreach: more than 6,000 views in April and May alone on NCSU grape portal;

***Strawberry*:**
Impact of stolon removal rates on daughter plant production of ever-bearing strawberry cultivars. M. Hoffmann, R. Hernández, G. Fernandez, X. Shi: Rates of propagation could be manipulated by harvesting intervals under CE conditions. We were able to produce more than 100 daughter plants per mother plant in 64 days. Manuscript submitted (MS Thesis)

Impact of NO3 - NH4 ratio on flower production and daughter plant production in ever-bearing strawberry cultivars.IM. Hoffmann, B. Jackson, X. Shi: Higher ratios of NH4 had suppressing effect on flower production. Manuscript in preparation (MS Thesis)

Steam in combination with AITC as non-chemical alternative to MBM. Hoffmann, S. Fennimore. Steam in combination with AITC had higher weed and pathogen control efficacy than any of the stand-alone treatments. Manuscript published.

Evaluation of weed and pathogen control efficacy of integrated methods (Steam, AITC, heat releasing substances) over different steam time exposure. M. Hoffmann, J. Neal, S. Fennimore, E Volk: Evaluating the efficacy of integrated management methods in Y1-2 and integrating results into nursery field steam applications, using state-of-the art soil steam technology in Y 3. (ongoing, funded by NASGA and USDA-NIFA MB Trans); (MS Thesis)

Impact of pre-plant fertilizer Nitrogen rates on Nitrogen movement in soil, plant establishment and strawberry production. M. Hoffmann, B. Jackson, A Woodley, M. Schroeder-Moreno, A. Lay: ongoing, partly funded by ICL and NC Strawberry Assoc.; (MS Thesis)

Impacts: Development of a collaborative multi-state SCRI project on optimizing strawberry plant propagation, with the long-term aim to create tools for clean strawberry plant production; Development of integrated soil disinfestation methods with steam, collaborative effort with UC Davis ($500,000 USDA Methyl Bromide Transition; $110,000 to NC State). Two virtual strawberry field days and a virtual strawberry pre-plant meeting, in total more than 150 participants. Agent training on strawberry cultural and pest management strategies in NC in December. COVID-19 related outreach: more than 20,000 views in April and May alone on NCSU strawberry portal;

Objective 3 - Explore the association between fruit constituents and human health impacts

***Blueberry*:**

Characterized bioactive bio-accessibility in blueberry germplasm (Massimo Iorizzo in collaboration with Food Scientists and NCGR-OR). A high-throughput in vitro digestion model was developed and implemented for the first time to evaluate phenolic bioaccessibility in blueberry. Moderate genetic heritability for absolute and relative bioaccessibility was estimated for several phenolics. Acylated anthocyanin had significantly higher relative bioaccessibility. Relative and absolute bioaccessibility can be measured and used as phenotypic traits to improve delivery of phenolics in new blueberry cultivars (Molla et al., 2020b).

2. How have the results been disseminated to communities of interest? What do you plan to do during the next reporting period to accomplish the goals?

Blackberry and raspberry: Results/discussion of the PCa and GWAS/Pairwise experiment were shared at the SE Regional Fruit and Vegetable Conference in Savannah GA in January and at the NARBA meeting in St. Louis in March.

Blueberry: Results are published along with a seminar at the annual NC Blueberry Council meeting in January.

Grape: Muscadine: Anthocyanin results from crosses of V. popenoi and V. rotundifolia were presented at the 2020 ASHS conference and the abstract will be published on line in December 2020.

Results for all fruit are disseminated through the NC Fruit Extension Team (https://ncfet.cals.ncsu.edu/), list-servs, webinars and online grower meeting, and the grape extension portal: https://grapes.ces.ncsu.edu/
Strawberries: Results are disseminated through the NC Fruit Extension Team

(https://ncfet.cals.ncsu.edu/), list-servs, webinars and online grower meeting, and the strawberry extension portal: https://strawberries.ces.ncsu.edu/
Strawberry GWAS-Antracnose study was presented at the NAPB meeting, virtually.

3. Include any data, germplasm/cultivar descriptions, research results, etc. that you would like to discuss at the meeting. Please keep this brief, highlighting no more than three discussion points within 500 words. Additional information (data tables, abstracts, etc…) can be included in an appendix.

4. List retrievable or archived publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications. Please use ASHS style.

- Fernandez, G., Pattison, J., Perkins-Veazie, P., Ballington, J. R., Clevinger, E., Schiavone, R., Gu, S., Samtani, J., Vinson, E., McWhirt, A., & Chacón, J. (2020). 'Liz' and 'Rocco' Strawberries, HortScience horts, 55(4), 597-600. Retrieved Jun 24, 2020, from https://journals.ashs.org/hortsci/view/journals/hortsci/55/4/article-p597.xml
- Bradish, C.M., J. M. Bushakra , L. R. Robbins , E. Karaadac, S. Teo, J. L. Willard, P. Perkins-Veazie, J. Lee, J. C. Scheerens, C.A. Weber , M. Dossett , N. V. Bassil, C. E. Finn and G. E. Fernandez. 2020. Standardized Phenotyping in Black Raspberry. Amer. Pom. Soc. 74 (1): 2-17
- Jacobs, R.L., T. B. Adhikari, J. Pattison, G. C. Yencho, G. E. Fernandez, and F. J. Louws. 2019. Assessing Rate-Reducing Foliar Resistance to Anthracnose Crown Rot and Fruit Rot in Strawberry. Plant Disease, Vol. 104, No. 2:, 398-407. https://apsjournals.apsnet.org/doi/10.1094/PDIS-04-19-0687-RE?ai=rs&ui=1z2&af=T
- Chacon Jimenez, Jose Guillermo (2019-12-13). Strawberry Studies: Screening of Germplasm and Identification of Quantitative Trait Loci for Necrotrophic and Hemibiotrophic Resistance to Anthracnose Diseases, and Validation of a Set of SSR Fingerprinting Markers.
- Chacon, J.G.1, Olukolu, B., Iorrizo, M., Louws, F.J. & Fernandez, G.Genome Wide Association Studies in an Octoploid Strawberry Biparental Population Discover QTLs for Hemibiotrophic and Necrotrophic Infection Resistance to Colletotrichum acutatum and C. gloeosporioides. NAPB annual meeting. Aug 2020.
- Mengist M.F., Grace M.H, Xiong J., Kay C.D., Bassil N., Hummer K., Ferruzzi M., Lila M.A. and M. Iorizzo (2020). Diversity in metabolites and fruit quality traits in blueberry enables ploidy and species differentiation and establishes a strategy for bioactive genetic studies. Frontiers in Plant Science, 11:370. https://doi.org/10.3389/fpls.2020.00370
- Farneti B., Emanuelli F., Giongo L., Toivonen P., Iorizzo M., Folta K.M. and C.E. Finn. 2020. Editorial: Interdisciplinary Approaches to Improve Quality of Soft Fruit Berries" to be considered for publication in Frontiers in Plant Science,

section Crop and Product Physiology. Frontiers in Plant Science, 11:592222. https://doi.org/10.3389/fpls.2020.592222

- Mengist M.F., Burtch H., Debelo H., Pottorff M., Bostan H., Nunn C., Corbin S., Kay C.D., Bassil N., Hummer K., Lila M.A., Ferruzzi M. and M. Iorizzo. 2020. Diversity of phenolic bioaccessibility in blueberry germplasm: towards the development of a genetic framework to improve the efficiency of bioactive delivery. Scientific Report, 10, 17311. https://doi.org/10.1038/s41598-020-74280-w
- Iorizzo M, Lila MA, Perkins-Veazie P, Pottorff M, Finn C, Vorsa N, Edger P, Bassil N, Munoz P, Zalapa J, Gallardo KR, Atucha A, Main D, Giongo L, Li C, Polashock J, Sims C, Canales E, DeVetter L, Chagne D, Espley R and Coe M. VacciniumCAP, a community-based project to develop advanced genetic tools to improve fruit quality in blueberry and cranberry. XXVII Plant & Animal Genome, January 11-15, 2020, San Diego, California, USA.
- Perkins-Veazie, P., Trandel, M. A., Fernandez, G. A Rapid Method for Estimating Titratable Acidity in Tomato and Small Fruits . 2019. ASHS Conference Proceedings, 54: S212 (abstract). https://journals.ashs.org/hortsci/view/journals/hortsci/54/9S/hortsci.54.issue-9S.xml
- Hoffmann, M., Talton, W., Nita, M., Jones, T., Al Rwahnih, M., Sudarshana, M.R. and Almeyda, C. 2019. First Report of Grapevine Red Blotch Virus, the causal agent of Grapevine Red Blotch Disease in Vitis vinifera in North Carolina. Plant Disease. https://apsjournals.apsnet.org/doi/full/10.1094/PDIS-07-19-1539-PDN
- Hoffmann, M., Ajwa, H.A., Westerdahl, B.B., Koike, S.T., Stanghellini, M., Wilen, C. and Fennimore, S.A. 2020. Multi-tactic pre-plant soil fumigation with Allyl Isothiocyanate (AITC) in cut-flower and strawberry. HortTechnology 30(2):251-258.
- Kim, D.S., Hoffmann, M., Kim, S., Scholler, B.A. and Fennimore, S.A. 2020. Integration of steam with allyl-isothiocyanate for soil disinfestation. HortScience 55(6):920-925.
- Hoffmann, M., Talton, W., Nita, M., Jones, T., Al Rwahnih, M., Sudarshana, M.R. and Almeyda, C. 2020. First report of grapevine leafroll-associated virus 3 (GLRaV-3) in Vitis vinifera in North Carolina. J. Plant Pathol (accepted).
- Shi, X., Hernández, R. and Hoffmann, M. 2020. Timing of stolon removal alters daughter plant production and quality in the long-day strawberry (Fragaria x ananassa) cultivar 'Albion'. HortScience (submitted).
- Michuda, A., Goodhue, R.E., Hoffmann, M. and Fennimore, S.A. 2020. Predicting net returns of organic and conventional strawberry following soil disinfestation with steam or steam plus additives. Agronomy (submitted).
- Master Thesis: Impact of Stolon Removal Intervals and Nitrogen Source Ratios on Propagation of Long-day Strawberries (Fragaria ×ananassa 'Albion') in Soil-less Greenhouse and Controlled Environment Systems - Xiaonan Shi, 2020, NCSU (Advisor: Mark Hoffmann)
- Hoffmann, M., Volk, E., and Peres, N.. 2020. Hurricane Preparation and Recovery Guide for North Carolina Strawberry Plasticulture Producers. In:

McNulty, Steven; Gavazzi, Michael; Matchett, Karin, eds. Hurricane preparation and recovery in the Southeastern United States. Gen. Tech. Rep. SRS-xxx. Asheville, NC: USDA Forest Service, Southern Research Station.

- Hoffmann, M., Conner, P., Brannen, P., Burrack, H., Mitchem, W., Cline, B., Perkins-Veazie, P. and Poling, B. 2020. Muscadine production guide for the Southeast (Hoffmann, Hickey, Burrack (edts)) 36pp. https://content.ces.ncsu.edu/muscadine-grape-production-guide

APPENDIX

Utilizing *Vitis popenoei* to successfully increase the malvidin content of muscadine grape

Perkins-Veazie, P., T. Bland, G. Ma, J. Ballington

Muscadine grapes (*Vitis rotundifolia*) grow exceptionally well in the southeastern US. Fruit anthocyanin pigments in *V. rotundifolia* contain primarily diglucoside forms of delphinidin and cyanidin, with little acylation of pigments. In contrast, *V. vinifera* grapes primarily have monoglucoside forms of anthocyanins, mostly with acylation. Ideal wine and juice stability is thought to be obtained by use of grapes high in malvidin-3-glucoside, malividn-3,5-diglucoside, or high in malvidin anthocyanins with acylation. For many years, breeding efforts have been made to increase and alter the anthocyanin profile in muscadine grapes. *Vitis munsoniana* is a subtropical relative of *V. rotundifolia* and *V. popenoei* is a tropical relative. All three of these species were successfully used to generate Fennels 3-Way hybrid (25, 25, and 50% *V. rotundifolia, V. munsoniana* and *V. popenoei*, respectively). Crosses with Fennels 3-Way hybrid have been used in the University of Georgia breeding program to double the total anthocyanin content and increase malvidin-3,5-diglucoside content up to 60%. In North Carolina, crosses were made between DVIT 2970, a *V. popenoei* selection containing 74% of total anthocyanin as malvidin-3,5-diglucoside, and a *V. munsoniana* x *V. rotundifolia* selection, FL 17:66, that is high in total anthocyanin content (>4,000 mg/100 g dry weight). Fruit from five of the seedlings from this cross were collected in 2018 and 2019 and anthocyanin profiles of freeze-dried peels determined using HPLC. One DVIT 2970 x 17:66 selection, CH 19:25-31, was found to be high in total anthocyanin (4100-6900 mg/100 g dry weight) and with over 76-79% of this as malvidin-3,5- diglucoside in both years. Percent malvidin-3,5-diglucoside among the five seedlings ranged from 50 to 79 of total pigments and total anthocyanin from 1500 to 6900 mg/100 g. These results indicate that *V. popenoei* can be used to shift anthocyanin profiles in muscadine grape to a high malvidin percentage without loss of total anthocyanin.

NCCC212 virtual meeting 2020 North Dakota State University

Evaluation of performance of small fruit selections in North Dakota. Harlene Hatterman-Valenti, Esther McGinnis, Janet Knodel, and David Dai**.**

Graduate students: Caitlin Krueger PhD, Andrej Svyantek PhD, Sarah Borgenrief MS, Venkateswara Kadium MS, and Jacob Lachowitzer MS

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Grapes: Initiated a germplasm enhancement project in 2009 with the goal of developing one red and white wine grape that will be winter hardy to -40 F without protection and ripen with only 1800 GDD base 50 F. Utilizing *V. riparia* for winter hardiness. Have planted 18 advanced selections into replicated trials at five locations in comparison to industry standards and have sent two selections that have been approved for pre-release to five states.

Juneberry: Collected native Juneberry biotypes for nursery evaluation in comparison to the most common cultivars available in Canada and the US. Continue to evaluate thirty-one biotypes and 14 named cultivars at two locations (Williston and Absaraka) for phenotypic and fruit yield evaluations. Yield data gathered from harvests over the past three years indicate up to 10 biotypes have superior attributes compared to 14 named cultivars. One nursery is interested in the biotype with upright characteristics, which is one of two approved for pre-release.

Other small fruit crops: Dr. Dai continues to test chokecherry lines for resistance to X-disease. Hatterman-Valenti continues to evaluate black currant germplasm from BC breeder and continues to evaluate blackberry production methods.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Grapes: For two winters in a row devastating dieback of almost all cultivars occurred in a variety trial initiated in 2004 despite what was considered a rather mild winter. Ranking of cultivars from least injury to most injury would be: Valiant, » King of the North » » John Viola, Baltica » » MN1131, Bluebell, Frontenacs (noir, gris, blanc) » » » St. Croix, Marquette, Sabrevois, Crimson Pearl, Petite Pearl, Prairie Star, Brianna, Alpenglow, Summerset Seedless, La Crescent, Verona » » » » Marcehal Foch, GR 7, Leon Merlot, Laura's Laughter, Louise Swenson, Edelweiss.

A trial to examine the effects of four trellis systems for 'Marquette' and 'Petite Pearl' grapes was also severely damaged repeatedly by winter dieback. No trellis system did better for trunk survival and the same was true for the two cultivars.

Trials also continue to assess the effect of viticultural practices (fruit zone leaf removal, shoot thinning, crop positioning, and crop load management) on fruit yield, quality, and vine cold hardiness for 'Frontenac', 'Marquette', and 'Prairie Star'. Another trial is screening the North Dakota State University grape germplasm collection for temperature adaptive acclimation responses. A joint trial with the UM (Clark) is evaluating how soils impact cold hardy grapes and wine quality. Lastly, a trial was initiated in 2020 to identify economically important fruit quality traits in diverse grape genotypes for elite germplasm development.

Blackberry and Raspberry: Continue to evaluate ways to get more fruit from primocane blackberry cultivars. Continue to evaluate organic production methods for raspberry and blackberry cultivars.

Other small fruit crops: A PhD student continues to evaluate SWD distribution and presence in small fruit somewhat unique to North Dakota. So far, there appears to be little to no connection between penetrometer values and reproductive success on tested cultivars. While not definitive, initial results suggest that skin toughness among small ND fruits is not the deciding factor in host preference or resistance.

Objective 3 - Explore the association between fruit constituents and human health impacts
Collaboration with Dr. Shetty to selectively modify and stimulate the phenolic profiles using system-based metabolic innovation and up-regulation of key defense related pathways to enhance both fruit quality and longevity during post-harvest stages for grape and blackberry.

2. List short and sweet impact statements under each objective.
North Dakota has some unique environmental challenges that must be overcome for successful small fruit production. Through germplasm enhancement and by examining practices to hastening ripening or extend the season and avoid winter injury, profitable farm diversification practices and locally produced small fruit will become available.

4. **List publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications.** Please use ASHS style (examples pages 14-15 of pdf at http://c.ymcdn.com/sites/www.ashs.org/resource/resmgr/files/style_manual.pdf).
Presentations:

Espe, A. D. Sarkar, H. Hatterman-Valenti, and K. Shetty. (2019). Phenolic antioxidant-linked anti-diabetic properties of blackberry cultivars using rapid *in vitro* assay models. North American Raspberry and Blackberry Conference, Savanna, GA Jan. 9-11, 2019.

Espe, A. C. Auwarter, and H. Hatterman-Valenti. (2019). Organic versus conventional production of primocane blackberries in North Dakota. North American Raspberry and Blackberry Conference, Savanna, GA Jan. 9-11, 2019.

Espe, A. D. Sarkar, H. Hatterman-Valenti, and K. Shetty. (2019). Phenolic antioxidant-linked anti-diabetic properties of serviceberry cultivars and accessions using rapid *in vitro* assay models. North American Raspberry and Blackberry Conference, Savanna, GA Jan. 9-11, 2019.

Stenger, J. and H. Hatterman-Valenti. (2019). Weed management options in cold hardy grapes. 72nd Annual Conference of the Western Society of Weed Science (WSWS) Denver, CO, Mar. 11-14, 2019.

Hatterman-Valenti, H., A. Espe, J. Stenger, and C. Auwarter. (2019). Primocane blackberry cultivar response to pseudo double-cropping. XII Rubus & Ribes Symposium, International Society Horticulture Science, Zurich, SZ, June 25-28, 2019.

Espe, A. D. Sarkar, H. Hatterman-Valenti, and K. Shetty. (2019). Phenolic bioactive-linked type 2 diabetes relevant functionalities and blackberry ripeness. XII Rubus & Ribes Symposium, International Society Horticulture Science, Zurich, SZ, June 25-28, 2019.

Espe, A. D. Sarkar, H. Hatterman-Valenti, and K. Shetty. (2019). Phenolic bioactives in unripe and ripe blackberry fruits targeted for type 2 diabetes using *in vitro* assay models. XII Rubus & Ribes Symposium, International Society Horticulture Science, Zurich, SZ, June 25-28, 2019.

Svyantek, A. and H. Hatterman-Valenti. (2019). Viticulture practices geared towards improving fruit quality. Montana Grape and Winery Association 5th Annual Meeting and Conference, Mar. 21-23, 2019, Helena, MT.

Svyantek, A., J. Stenger, I. Tatar, N. Thiesen, C. Auwarter, H. Hatterman-Valenti. (2019). Growth Chamber Analysis of Dormancy Acclimation Response of NDSU Grape Germplasm. American Society for Enology and Viticulture- Annual Conference. Napa, CA.

Lachowitzer, J., A. Svyantek, J. Stenger, and H.Hatterman-Valenti. (2019). Yeast influenced on 'Petite Pearl' and 'Crimson Pearl' wine sensory attributes. American Society for Enology and Viticulture – Eastern Section 44rd Annual Conference, July 16-18, 2019, Geneva, NY.

Svyantek, A. J. Stenger, C. Auwarter, N. Theisen, M. Brooke, and H. Hatterman-Valenti. (2019). Leaf removal practices alter cluster morphology and soluble solid content of North Dakota grown 'Marquette'. American Society for Enology and Viticulture – Eastern Section 44rd Annual Conference, July 16-18, 2019, Geneva, NY.

Hatterman-Valenti, H., J. Stenger, A. Svyantek, N. Theisen, R. Ibrahim, C. Auwarter. (2019). Delayed Pruning Does Little to Mitigate Risk of Late Spring Frost in North Dakota Grown Cold-Hardy Grapevine Cultivars. American Society for Enology and Viticulture – Eastern Section 44rd Annual Conference, July 16-18, 2019, Geneva, NY.

Hatterman-Valenti, H. and A. Svyantek. (2019). North Dakota State University Grape Germplasm Enhancement Project. North American Grape Breeders Conference. Aug. 15-16, 2019, Springfield, MO.

Svyantek, A., J. Stenger, N. Thiesen, I. Tatar, M. Brooke, Z. Rivera, C. Auwarter, H. Hatterman-Valenti. (2019). Improving Fruit Quality in Cool-Climate Viticulture Under Inclement Environmental Conditions. Food for Health Workshop. Hunan Agricultural University. Changsha, Hunan. China.

Publications:

Askari-Khorasgani, O., H. Hatterman-Valenti, F. Pardo, and M. Pessarakli. 2019. Plant and symbiont metabolic regulation and biostimulants applicaation improve symbiotic performance and cold acclimation. J. Plant Nutrition. 42(17):2151-2163.

Askari-Khorasgani, O., H. Hatterman-Valenti, F. Pardo, and M. Pessarakli. 2019. Managing plant-environment-symbiont interactions to promote plant performance under low temperature stress. J. Plant Nutrition. 42(16):2010-2027.

Debner, A., H. Hatterman-Valenti, and F. Takeda. 2019. Blackberry propagation limitations when using floricane cuttings. HortTechnology. 29(3):276-283.

Agriculture and Agri-Food Canada

Kentville Research and Development Centre
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1. List your research and extension projects under the official NCCC 212 objectives, emphasizing collaborative projects with other researchers. A suggested format is below.

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

The Canadian Berry Trial Network. B. Amyotte, AAFC, Nova Scotia; E. Gerbrandt, Sky Blue Horticulture, British Columbia; M. Dossett, B.C. Berry Cultivar Dev. Inc., British Columbia; J. Zandstra, A. Dale, University of Guelph, Ontario; P. Lafontaine, Carrefour Industriel et Expérimental de Lanaudière, Québec. 2018-2023

Strawberry, Raspberry, Blueberry
The Canadian Berry Trial Network (CBTN) is an industry- and public-funded variety trial network for strawberry, raspberry and blueberry. The trials are conducted at agricultural research institutions in British Columbia, Ontario, Quebec and Nova Scotia. All trials are planted in outdoor field plots as RCBDs and managed under regional production methods.

The CBTN invites NCCC212 members and colleagues to send us your new advanced selections and varieties of strawberry, raspberry and blueberry. The trials are an opportunity to test your pre-commercial selections and to show Canadian growers how your named varieties perform in their regions. We will plant new trials in spring 2021 and 2022. Interested? Please contact B. Amyotte: beatrice.amyotte@canada.ca

Strawberry Variety Development. A. Jamieson, B. Amyotte, AAFC, Nova Scotia. 2016-2021

Strawberry
Three new strawberry varieties have been released from the Nova Scotia breeding program. They are: 'AAC Audrey', 'AAC Evelyn' and 'AAC Kate'. The varieties were bred by Andrew Jamieson and selected in collaboration with two Canadian berry nurseries. The formal prefix 'AAC' designates Agriculture and Agri-Food Canada.

'Audrey', 'Evelyn' and 'Kate' are June-bearing strawberries with medium-large, firm berries that ripen in the mid-season with 'Mira' and 'Lila'. They have moderate yields in Nova Scotia and Quebec, and are currently being tested in other Canadian provinces. North American plant sales are licensed to Lareault Nursery in Quebec and C.O. Keddy Nursery in Nova Scotia. Variety protection is in progress, and plants will soon be available for sale in the USA.

Raspberry Redomestication. M. Dossett, BC Berry Cultivar Dev. Inc., British Columbia; G. Zdanowicz, AAFC, British Columbia; B. Amyotte, AAFC, Nova Scotia. 2018-2023

Raspberry
In 2018, M. Dossett evaluated a diverse collection of wild *Rubus idaeus* plants in a field trial at Clearbrook, British Columbia, selected individual plants based on plant health and fruit quality, and made crosses among the selections. In 2019, M. Dossett and G. Zdanowicz seedlings from these crosses to the AAFC Kentville Research and Development Centre in Nova Scotia. The seedlings will be evaluated in Kentville in 2021 and 2022, and the best selections will be intercrossed. The population will be sent back and forth between British Columbia and Nova Scotia for 2-3 generations. The objective is to build a new germplasm pool for raspberry breeding, with emphasis on adaptation to variable climates.

Strawberry Diversity Collection Evaluation. B. Amyotte, AAFC Nova Scotia; B. Fofana, AAFC, Prince Edward Island; K. Hummer, USDA, Corvallis, OR; K. Hummer collaborators (many, various locations). 2019-2022

Strawberry
In 2019, K. Hummer sent a collection of 300 *Fragaria* x. *ananassa* accessions from the USDA clonal germplasm repository in Oregon to the AAFC Kentville Research and Development Centre in Nova Scotia. This collection has previously been genotyped and phenotyped for various plant and fruit characteristics in Corvallis and elsewhere. The collection was planted in Kentville in summer 2020 and will be phenotyped for phenological and fruit quality traits in 2021 and 2022. The Nova Scotia data will be integrated into the larger study to serve as another dimension of genotype x environment for the genome wide association study. The objective is to identify new genetic sources of variation for breeding and selection.

2. List brief impact statements as they relate to each objective. How have the results been disseminated to communities of interest? What do you plan to do during the next reporting period to accomplish the goals?

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

The AAFC small fruit germplasm development program serves small fruit growers across Canada through breeding, variety evaluation and germplasm development. Our plants and data have strong relevance to NCCC212 members and stakeholders. The breeding program is focused primarily on June bearing strawberry: our three new releases, selected in Nova Scotia, Canada, are 'AAC Audrey', 'AAC Evelyn' and 'AAC Kate.' These varieties are licensed to Lareault Nursery and C.O. Keddy Nursery, and will soon be available for purchase in the USA. The Canadian Berry Trial Network is our vehicle for testing new varieties of strawberry, raspberry and blueberry, and disseminating trial results with growers. Annual updates and trial results are disseminated to our grower associations through regional meetings and through our CBTN Google drive. We welcome the addition of new genetics from university, public and private breeding programs on an annual basis. Lastly, AAFC's germplasm development work includes evaluating diverse strawberry and raspberry populations with the goal of increasing breeding resources in the long term. Interim results from this work will be discussed with NCCC212 members throughout the projects, and final results will be submitted for scientific publication upon completion.

3. Include any data, germplasm/cultivar descriptions, research results, etc. that you would like to discuss at the meeting. Please keep this brief, highlighting no more than three discussion points within 500 words. Additional information (data tables, abstracts, etc…) can be included in an appendix.

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

The Canadian Berry Trial Network

The CBTN invites NCCC212 members and colleagues to send us your strawberry, raspberry and blueberry plants. The trials are an opportunity to test pre-commercial selections and new commercial varieties in Canada.

The CBTN planted strawberry and raspberry trials in 2019 and 2020. The trials include new varieties and trial selections from AAFC Nova Scotia (A. Jamieson), AAFC Quebec (S. Khanizadeh), U. Guelph (A. Dale) and B.C. Berry Cultivar Development Inc. (M. Dossett) alongside commercial standards. The trial sites are located at the Agassiz Research and Development Centre in British Columbia (E. Gerbrandt and M. Dossett), the University of

Guelph in Ontario (J. Zandstra and A. Dale), the Carrefour Industriel et Experimental in Quebec (P. Lafontaine) and the Kentville Research and Development Centre in Nova Scotia (B. Amyotte). All trials are managed under standard conventional outdoor production practices in each region. Data collection and analyses are ongoing.

We are planning new trials for strawberry, raspberry and blueberry in 2021 and 2022, and we would like to expand our variety mix to include more material from U.S. breeding programs. To plant a full trial in 2021, we would need about 200 plants per variety for strawberry, 100 for raspberry, and 80 for blueberry. We welcome entries from university, public and private breeding programs. We are able to write custom testing agreements with your institution to ensure your germplasm is well protected. Please send me an email if you would like to discuss the program: beatrice.amyotte@canada.ca.

Strawberry Variety Development

'**AAC Audrey**'
A new June bearing strawberry variety developed in Nova Scotia, Canada, by Andrew Jamieson. 'AAC Audrey' was selected in 2013 as 'K13-11' and named in 2018. It is derived from a cross of 'K04-21', a Kentville selection with medium productivity and medium-high fruit quality, and 'AAC Lila', a cultivar released in 2013 with medium productivity and sweet, attractive fruit. 'Audrey' ripens in the mid-season, at the same time as 'Lila'. It has medium yields, medium-large berries with good firmness and shelf-life, and a consistent conic shape. The plant has some susceptibility to powdery mildew.

'**AAC Evelyn**'
A new June bearing strawberry variety developed in Nova Scotia, Canada, by Andrew Jamieson. 'AAC Evelyn' was selected in 2013 as 'K13-19' and named in 2018. It is derived from a cross of 'K11-9', a Kentville selection with medium productivity and medium fruit quality, and 'K09-4', a Kentville selection with medium productivity and very firm fruit. 'Evelyn' ripens in the mid-late season, at the same time as 'Mira'. It has medium-high yields, large berries with good firmness, medium shelf-life, and a wedge to conic shape. The plant has some susceptibility to powdery mildew and fruit have shown some sun scald.

'**AAC Kate**'
A new June bearing strawberry variety developed in Nova Scotia, Canada, by Andrew Jamieson. 'AAC Kate' was selected in 2012 as 'K12-14' and named in 2018. It is derived from a cross of 'K07-32', a Kentville selection with high productivity and low fruit quality, and 'K04-21', a Kentville selection with medium productivity and medium-high fruit quality. 'Kate' ripens in the mid-late season, at the same time as 'Mira'. It has medium yields, large berries with good firmness, medium shelf-life, and a mostly conic shape. 'Kate' berries have medium-high acidity, similar to 'Mira'. The plant has some susceptibility to powdery mildew.

North American plant sales are licensed to Lareault Nursery and C.O. Keddy Nursery. Variety protection is in progress, and plants will soon be available for sale in the USA.

4. List retrievable or archived publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications. Please use ASHS style.

N/A

Ontario

NCCC 212 Report
Ontario Berry Research Summary

Erica Pate, Ontario Ministry of Agriculture, Food and Rural Affairs; Kevin Schooley, Berry Growers of Ontario

Highlights:
New Specialty Crops Innovation Professor Dr. Melanie Kalischuk, University of Guelph
New Horticulture Pathologist, Katie Goldenhar, OMAFRA

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Strawberry:
Title: *Strawberry Anthracnose Fruit Rot Model Adoption*. E. Pate, OMAFRA, K. Schooley, Berry Growers of Ontario.

Day neutral strawberries are an emerging crop in Ontario. Anthracnose fruit rot was identified as a major problem in Ontario in the early 2000's. It became controllable from 2003-2005 with the registration of two closely related fungicides. Results from a previous project found populations of *C. nymphiae* on several strawberry farms to be resistant or moving toward resistance to the fungicides. Results from this project also verified a Strawberry Anthracnose Fruit Rot model (developed by Wilson et al. 1990) that reduces fungicide applications by better timing and targeting the fungicide applications and therefore reduce the exposure of the pathogen to the selection pressure of excess fungicide applications which reduces the risk of resistance developing in the future without compromising disease control, yield or berry quality under Ontario conditions. The 2019 'Strawberry Anthracnose Fruit Rot Model Adoption' project built on the results of the first project by helping 'early adopter' strawberry growers who are leaders in the Ontario strawberry grower community try the Strawberry Anthracnose Fruit Rot Model on their farms during the 2019 strawberry season.

The model used in Ontario was evaluated in trials in Florida, where thresholds for captan and pyraclostrobin applications were developed. The model was validated in 2016-2017 in Ontario conditions which determined that by using this model growers could reduce fungicide applications by 7-33%. The 2019 project built on these results, and 5 growers across the province used the model to gain experience and help with adoption.

All participants had similar feedback regarding their experience using this model: it

provided good information, was helpful in timing fungicide applications, and was a good tool to learn more about the conditions that lead to infection. However, there were two concerns with this model. The first issue is incorporating this model into a management program where other pests need to be managed and harvest schedules need to be maintained. For example, growers need to spray for insects such as spotted wing drosophila weekly, and for other diseases including powdery mildew weekly, whereas the model could be triggered every 10 days. The other factor in further adoption of this model is the economics. While growers acknowledge the benefit of reducing fungicide applications and spraying are needed, the reduced costs from fewer fungicides may not cover the costs of the system for smaller growers and will affect their bottom line.

Despite the challenges with pesticide timing some of the participants commented that they could be flexible with harvest dates or could use this model to make decisions on what products to apply weekly, instead of using the model to time an application.

Berry growers in Ontario are interested in using weather-based models to make informed decisions on pest management, and there is a growing need for conserving anthracnose fungicides with the concerns around fungicide resistance. Currently this model is not economical for most individual growers, however there is interest in pursuing options for regional monitoring or establishing a province-wide system for greater adoption of this model.

Title: *Waiting bed plants for strawberry fruit production.* E. Pate, OMAFRA; K. Schooley, Berry Growers of Ontario.

This project evaluated the potential to use mother plants for fruit production. Growbags with mother plants from a propagator were moved into an outdoor field onto raised beds. Multiple factors were evaluated during this project including the potential for this system to reduce labour requirements, reduce crop inputs, and increase profit. While there are benefits to this system including a shorter production period and reduced inputs, this system is more expensive than standard production systems (day neutrals or matted-row) and the benefits do not compensate for the increased expense. There was not a yield benefit to this system to compensate for the increased costs. There are opportunities to improve this system and increase yields and the viability of the system, however a more economical plant source is needed for this system to be feasible for growers.

Title: *Efficacy of biopesticides and new miticides for cyclamen mite in strawberry.* J. Renkema, AAFC; R. Hallett, University of Guelph.

This project is part of a larger project to test new controls and develop an integrated management system for cyclamen mite in strawberry. Strawberries were planted in May 2019, with cyclamen mites added in June. Miticides and biopesticides were applied in late June-early July. Agri-mek SC (abamectin), GWN-1708 (fenazaquin), Grandevo, Venerate, Bb Protec, EcoTrol, Vegol, and Agral 90 were tested. GWN-1708 (fenazaquin) was the most effective product and Venerate +EcoTrol were the most effective biopesticides. These products were assessed again in 2020 post-renovation. The data is currently being analyzed.

Blueberry:

Title: *Distribution of four major plant parasitic nematodes associated with highbush blueberry in Southern Ontario.* T. Sultana, AAFC; E. Pate, OMAFA; E. Thorpe, OMAFRA.

The goal of this project was to determine the occurrence and distribution of plant parasitic nematodes associated with blueberries in Southern Ontario. Most samples were positive for at least one plant parasitic nematode tested. 32% of samples were positive for dagger nematodes, a well-known vector for several viruses, which can cause blueberry decline. Not all common plant parasitic nematodes have been tested in this study and sample numbers were relatively low. A larger sampling is needed, and a follow up survey will be conducted in 2021.

Berries, Grapes:

Title: *Development of a novel method for quantifying SWD in a monitoring program in stone fruit, grapes and berries and determination of impact of SWD on stone fruit and grape varieties.* W. McFadden-Smith, OMAFRA; J. Renkema, AAFC; S. Chen, University of Guelph; J. Subramanian, University of Guelph.

Spotted wing drosophila (SWD) was monitored throughout the 2019 and 2020 growing season using liquid traps. After counting, samples were sent to the lab in 2019 for PCR testing to validate the calibrations established on lab material. Methodology was developed to quantify SWD using qPCR (quantitative polymerase chain reaction). The calibration formula is being refined in 2020 to relate physical counts to PCR results more precisely by creating a curve from degraded samples in water or an alternative liquid. The goal of this project is to develop a quick test for SWD monitoring to help growers optimize spray timing.

NCCC212 “Small Fruit and Viticulture” Report

October 27–28 2020
North Carolina State University (virtual)

Oregon State University

Prepared by Bernadine C. Strik
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Note: Not everyone working on berries or grapes at OSU contributed to this report

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Bernadine Strik is the OSU-lead on the USDA-ARS & OSU Cooperative Breeding Program formerly led by Dr. Chad Finn, USDA-ARS, HCRU, Corvallis; Chad tragically passed away Dec. 17 2019. Related activities have been summarized in a USDA/ARS report.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Blueberry

Development of alternate fertilization programs to mitigate nutrient problems found in long-term organic blueberry production systems (study in progress)

B.C. Strik, A.J. Davis, D.R. Bryla. Oregon State University and USDA-ARS

The goal of this project is to study the impact of alternative OMRI-approved fertilizers to mitigate the negative impacts observed with long-term use of a yard debris compost and fish solubles fertilizer as nutrient courses in organic blueberry. After eleven years of research on the impact of organic fertilizer source and mulch type on soil and plant tissue nutrients and plant performance, we learned that applications of high K through addition of yard-debris compost or via fertigation with fish solubles led to higher leaf and soil K and lower leaf Mg and Ca; these nutrient changes were correlated with lower yield in 'Duke'. Most organic growers in the Pacific Northwest rely heavily on fish solubles as a fertilizer source and many use composts (plant or animal based) as part of their nutrient management program. We thus expect that similar problems are occurring in many organic fields – unrealized yield through imbalances in soil and plant nutrient status from of high applications of K through compost and fertilizer programs. We are assessing the impact of changing fertilizer source and mulch type on improving soil and plant nutrient status to address these issues. The use of compost was ceased after the 2016 growing season, and the N-fertilizer source was changed from fish to a vegan product that can be fertigated (liquid BioLink 5.5–0–0 in 2017, water soluble BioLink 14–0–0 in 2018-20; Westbridge Agricultural Products). We planned to add Ca and Mg through use of other sources like feather meal, soybean meal, and gypsum but these were not necessary during the study. In addition, previous mulches (sawdust, sawdust with a layer of yard-debris compost underneath, or black weed mat), were either covered (sawdust and sawdust + compost) or replaced (weed mat) with new weed mat. Changes in yield and soil and plant nutrient status were measured. Since 2016, yield has generally increased except in 2017 when bird pressure was high and pollination was poor, as evidenced by reduced fruit and seed set. In both raised and flat beds, yield has increased the most in plots that previously had sawdust mulch and the least in plots that previously had weed mat. In flat beds, plots previously fertilized with the high rate of fish fertilizer continue to have lower yield than those fertilized with low rates of feather meal despite a 7–20% reduction of soil K. The addition of sulfur in spring 2019 mitigated what had been an increase in soil pH since 2016; pH dropped by around 10% by the fall of 2019 (soil samples for fall 2020 are

forthcoming). Soil organic matter continues to be influenced by previous mulches (highest in the plots that previously had sawdust + compost and lowest in plots with weed mat alone). Leaf N (%) has been consistently higher since 2016 while leaf K, Ca, Mg, and B have decreased across most treatments in all years. Correlation analysis (nutrient levels and yield) and analysis of changes in nutrient status will be evaluated for 200 treatment plots after the remaining data is collected for 2020.

Machine harvesting and low-input pruning options in 'Mini Blues' for specialized processed markets (study in progress)

B.C. Strik, A.J. Davis, P. Jones. Oregon State University and USDA-ARS

This study is being conducted at the NWREC in a 0.25-acre conventional planting of 'Mini Blues' established in Oct. 2015. Treatments are designed to develop best management practices for machine harvest using pruning techniques started in the winter of 2017-18 (after the second growing season): 1) a conventional pruning method including bottom and top cuts to the bush; 2) unpruned for several years [pruned hard every few years]; 3) hedging immediately after fruit harvest in summer; and 4) hand "speed" pruning in winter making only big cuts to base of bush. In winter 2019-20, dormant pruning required 171 hours/acre for conventional pruning, while speed pruning took only 34 hours/acre, and the hedge and no pruning treatments required an average of 13 hours/acre to clean up low growing branches. Mechanical hedging was not done after harvest in 2019 or 2020 because it was apparent that shoots that regrew after hedging in 2018 did not have enough time to develop fruit buds, resulting in reduced yield in 2019. 2020 was the third season in which fruit were machine harvested. Yield in the hedged plants recovered to a similar level as other treatments after a year of recovery. While in 2019 speed pruned plants had higher overall yield than hedged plants, in 2020 there were no significant differences in harvested yield or total plant yield (including dropped fruit and fruit remaining on the plant after harvest) among treatments. However, we did have increased bird pressure in 2020 resulting in greater variability and lower overall yield in all treatments except hedged than in the previous year. Unpruned plants had the most fruit remaining on the plant (606 g, or 23% of total yield) compared to speed and control treatments (averaging 272 g, or 9% of total yield). Control plants had a much higher percentage of fruit harvested on the first harvest (82%) compared to all other treatments (averaged 58%). Berry weight has also greater (0.7g/berry) compared to hedged and unpruned plants (0.6g) while speed pruned plants were intermediate (0.64 g). Brix (average 16.2%) was not affected by pruning. Leaf and soil nutrient status are being monitored, and an economic cost-benefit analysis will be done when the study is complete.

Pruning and training options for improving production efficiency in 'Legacy' blueberry
(study in progress)

B.C. Strik, A.J. Davis, P. Jones. Oregon State University and USDA-ARS

This study is being conducted at the NWREC in a 0.25-acre conventional planting of 'Legacy' established in Oct. 2015. Treatments are designed to develop best management practices for hand and machine harvest of 'Legacy' which has a growth habit and yield different from most Northern highbush blueberries grown in Oregon. Three pruning/training treatments began in winter 2017-18 (prior to year 3): 1) Typical Northern highbush pruning; 2) Standard 'Legacy' pruning, leaving more small, thin fruiting wood ("Control"; per Strik's recommendation for this cultivar); and 3) Control plus training to a V-shaped trellis with a goal of more efficient hand and machine harvest. In the prior winter (2018-19), pruning of the "V-trellis" plants required more time due to the additional work of tucking canes between the wires (196 hr/acre) compared to "control" (144 hr/acre) and "HB" (131 hrs/acre), while in the 2019-20 winter season, there was no significant difference between pruning methods, though the control and V trellis averaged approximately 30 hr/acre more than HB pruning. There was no difference in the amount of pruning wood removed in the 2019-20 dormant season (1.1 kg/plant for control and V; 1.4 kg/plant for HB). In 2020, the first two harvests were by hand and the third harvest was done by machine. Due to heavy bird pressure, we had lower than expected yield. However, 2020 was the first harvest year in which yield was affected by pruning. Plants with the standard 'Legacy' pruning on a V-trellis produced 9.5 tons/acre while HB pruning yielded 8.1 tons/acre (control yield was 9.2 tons/acre). HB pruning resulted in slightly faster ripening, with 56% of fruit harvested on the first pick compared to 50% in the V-trellis, but no differences were found in subsequent harvests. To date, pruning has not affected berry weight (2.2 g), Brix (14.7%), or percentage of fruit dropped on the ground during hand harvest (7-8% in 2018-2020). A greater fruit weight was dropped during machine harvest with the V-trellis in 2020, but the percentage of total yield dropped was not different from other treatments (averaged 18%). All pruning treatments required the same amount of time to harvest per kg of fruit.

*Individual and Combined Use of Sawdust and Weed Mat Mulch in a New Planting of Northern Highbush Blueberry I. Impacts on Plant Growth and Soil and Canopy Temperature (**Published**)*

B.C Strik, A.J. Davis, D.R. Bryla, and S.T. Orr. Oregon State University and USDA-ARS

A 2-year trial was established in Oct. 2016 in western Oregon to evaluate the effects of various in-row mulch treatments on establishment of northern highbush blueberry (*Vaccinium corymbosum* L. 'Duke'). The treatments included douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] sawdust, black weed mat (woven polypropylene ground cover), green weed mat, and sawdust covered with black or green weed mat. Soil temperature was unaffected by the color of the weed mat but was often higher during the day in beds with weed mat mulch than in those with sawdust alone or sawdust covered with weed mat. Black or green weed mat also resulted in higher canopy temperatures, particularly when sawdust was underneath the weed mat. For the most part, plant growth was

unaffected by the color of the weed mat, and the maximum depth of root system was similar among the mulch treatments. However, plants grown with sawdust mulch, with or without weed mat, had greater canopy width and volume in year 2, a wider root system in both years, and more dry weight (DW) in the crown in year 1 and in the whips in year 2 than those with weed mat alone. Furthermore, plants with weed mat over sawdust were taller in year 1 and had greater canopy cover and more DW in new wood in year 2 than those with sawdust alone, and they had a larger canopy, more root development, and greater DW in the crown, new and old wood, fruit, and pruning wood in one or both years than those with weed mat alone. Over the 2 years of the study, net gain in total plant DW was lowest when the plants were grown with black weed mat and highest when they were grown with black weed mat over sawdust. While it was more expensive initially, the use of weed mat over sawdust resulted in more plant growth than weed mat alone due to the insulating properties of the sawdust and was more effective for weed control than using sawdust alone.

*Individual and Combined Use of Sawdust and Weed Mat Mulch in a New Planting of Northern Highbush Blueberry II. Nutrient Uptake and Allocation (**in press; HortScience**)*

B.C Strik, A.J. Davis, and D.R. Bryla. Oregon State University and USDA-ARS

A 2-year trial was established in Oct. 2016 in western Oregon to evaluate the effects of various in-row mulch treatments on establishment of northern highbush blueberry (*Vaccinium corymbosum* L. 'Duke'). The treatments included douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] sawdust, black weed mat (woven polypropylene ground cover), green weed mat, and sawdust covered with black or green weed mat. For the most part, plant nutrient concentration and content were unaffected by the color of the weed mat. In both years, mulching with weed mat over sawdust reduced soil NO_3-N as compared to weed mat alone. The only other soil nutrient affected by mulch was K, which was highest with sawdust mulch and intermediate with black weed mat alone in year 2. There were inconsistent effects of mulch on leaf nutrient concentration during the study. In 2018, leaf N concentration was lowest with black weed mat over sawdust. There were few mulch effects on nutrient concentrations in senescent leaves in both years and in harvested fruit in year 2. Mulch had more effect on nutrient concentration in dormant plant parts after the second growing season than after the first, with the addition of sawdust under weed mat leading to significant differences for many nutrients in various plant parts as compared to weed mat alone. Total uptake of N ranged from 12 $kg \cdot ha^{-1}$ (black weed mat) to 17 $kg \cdot ha^{-1}$ (black weed mat over sawdust) in year 1 and averaged 33 $kg \cdot ha^{-1}$ in year 2, with no effect of mulch. Fertilizer use efficiency for N was 8% to 12% in year 1 and 42% in year 2. Uptake of other nutrients was unaffected by mulch and, depending on the year, ranged from 1.3–4.3 $kg \cdot ha^{-1}$ P, 4.0–8.0 $kg \cdot ha^{-1}$ K, 2.1–4.9 $kg \cdot ha^{-1}$ Ca, and 1.0–1.5 $kg \cdot ha^{-1}$ Mg. Each of these other nutrients were derived from the soil or decomposing roots.

*Individual and Combined Use of Sawdust and Weed Mat Mulch in a New Planting of Northern Highbush Blueberry III. Yield and Fruit Quality (**in Progress**)*

B.C Strik and A.J. Davis. Oregon State University

A 4-year trial was established in Oct. 2016 in western Oregon to evaluate the effects of various in-row mulch treatments on establishment of northern highbush blueberry (*Vaccinium corymbosum* L. 'Duke'). The treatments included douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco] sawdust, black weed mat (woven polypropylene ground cover), green weed mat, and sawdust covered with black or green weed mat. In 2018, yield was higher in black+sawdust compared to black, while there were no differences in yield for 2019, 2020, or cumulatively. Berry weight and berry diameter were greater in 2018 and 2020 compared to 2019 while total soluble solids (TSS) and firmness were highest in 2018 compared to other years. Across all three years, black+sawdust had larger fruit (18.5 mm diameter) than black (18.1 mm) while black and sawdust alone had higher TSS (averaged 13.9%) than black+sawdust and green+sawdust (averaged 13.2%). Fruit were ripe earlier with sawdust mulch in 2018 while timing of harvest was not affected by mulch in 2019 or 2020. Berry weight and firmness were not affected by mulch treatment in any year.

Management Techniques to Optimize Soil pH and Nutrient Availability in Organic Highbush Blueberry Grown East of the Cascade Range (study in progress, year 1 of 3)

S.B. Lukas[1], L.W. DeVetter[2], D.R. Bryla[3], B.C. Strik[1], J. Fernandez-Salvador[1] and S. Galinato[2]. [1]Oregon State University, [2]Washington State University and [3]USDA -ARS

Organic blueberry production in Oregon and Washington is predominately located in the semi-arid region east of the Cascade Range. While the size of the industry has increased, research support has not. Consequently, many of the horticultural issues that have emerged remain unresolved, specifically regarding nutrient management. Growers report that managing soil pH and organic matter are their foremost concerns that limit production and long-term viability. Blueberry requires very specific pH and organic matter conditions. There are limited research-based recommendations to advise growers on how to best modify soil pH and provide organic matter. The goal of this project is to develop optimized nutrient strategies to facilitate industry expansion and environmental stewardship. Specifically, we are evaluating modified practices including (obj. 1) the novel use of pelleted sulfur as a slow release method, (obj. 2) acidified grape pomace, and (obj. 3) alternative biochar feedstocks produced at reduced temperatures for lower pH. These objectives are intended to relieve industry bottlenecks to improve pH and organic matter in organic blueberry. Research will be complimented with (obj. 4) a complete cost-benefit analysis to determine the economic impacts and viability of investigated practices. We will develop (obj. 5) rigorous educational programs related to planting establishment and nutrient management, including dissemination of project information and evaluation of impact. This project will provide producers in this region and throughout the U.S. with valuable applied outcomes to optimize production.

Blackberry/Raspberry

*Alignment between University Nutrient Guidelines and Grower Practices for Blackberry and Red and Black Raspberry in Oregon (**in press; J. Amer. Pom. Soc.**)*

Jones, P.A., A.J. Davis, and B.C. Strik. Sr. Faculty Research Assistant I, Sr. Faculty Research Assistant I, and Professor, Oregon State University

Information was gathered from 13 caneberry (blackberry and red and black raspberry; *Rubus* spp.) growers in Oregon's Willamette Valley in 2018 to learn which nutrient management tools growers were using and to determine relationships between plant (leaf and fruit) and soil nutrient status and planting performance for various cultivars. The floricane-fruiting caneberry cultivars studied were 'Meeker' red raspberry, 'Munger' black raspberry; 'Black Diamond', 'Columbia Star', 'Marion', and 'Obsidian' trailing blackberry; and 'Triple Crown' semi-erect blackberry. Our goal was to understand key challenges and questions that remain after many years of nutrient management research and extension outreach. Considerable variation in fertilization practices among grower sites was found. Several growers were applying fertilizer within the recommended rates and had good plant growth and yield, but many sites in this study included fields that were not performing to their full potential. Key problems identified that may have reduced plant performance and yield included soil pH lower than the recommended range of 5.6–6.5, likely reducing nutrient availability; in the study, 28% had a soil pH below 5.6 and some had a pH as low as 4.6. Soil levels of P, K, and Mg were generally high across grower sites indicating no fertilizer was needed, yet many growers fertilized with P and K regardless. Many growers applied excessive rates of N fertilizer from sources that would exacerbate low pH, and timed applications improperly based upon existing extension recommendations. Site or grower management impacted the concentration of almost all leaf nutrients within cultivars, with deficient levels for N, P, K, and Ca at many sites. Site had a significant impact on the concentration of many fruit nutrients. Fruit %P, K, Ca, Mg, and S were positively correlated with their respective leaf concentrations. Percent moisture content of fruit ranged from 72–86% and was affected by grower management for 'Black Diamond', 'Munger', 'Obsidian', and 'Triple Crown'. Despite adequate to high N fertilizer rates being applied, leaf %N was low or just sufficient, supporting the hypothesis that management practices were limiting fertilizer uptake. Some growers applied granular product while drip irrigating, likely reducing availability of nutrients during periods of demand. Insufficient irrigation at key times of the season or stages of plant development may have limited plant uptake of N and K. While current recommendations are to collect soil samples every few years and leaf tissue samples annually to assess nutrient management programs, many growers were not doing so. Growers most frequently relied on fertilizer company field representatives regarding best nutrient management practices rather than using free extension resources for sampling and fertilization methods. Improved outreach to company representatives and revising nutrient management publications to incorporate new research-based information will be key in helping the industry better monitor soil and leaf nutrient status and manage fertilizer requirements in their caneberry crops.

*Impact of planting density and pruning and training method on growth, yield and machine-harvest efficiency of 'Columbia Star' trailing blackberry (**in progress**)*

Strik, B.C. and A.J. Davis. Oregon State University

A new planting of 'Columbia Star' trailing blackberry was established in spring 2020 to study the impact of plant spacing (0.75 m vs. 1.5 m), primocane management (with or without chemical primocane suppression), and pruning/training (August training vs. un-pruned or "new-over-old") treatments on growth, yield, fruit quality, machine-harvest efficiency, and labor requirements. Primocanes were trained as they grew in 2020. First machine harvest and pruning and training treatments will begin in 2021.

Strawberry

Evaluation of low tunnels for season extension of fresh-market, day-neutral strawberries in Oregon's Willamette Valley (study in progress)

Javier Fernandez-Salvador, Erica Chernoh, and Cora Bobo-Shisler, Oregon State University.

A two-year study (2019-2020) is being conducted at the OSU North Willamette Research and Extension Center (NWREC) in Aurora, OR tracking the growth and production of day-neutral strawberries grown in low tunnel plasticulture. Containerized transplants potted from bare-root plants were grown in the greenhouse for 6 weeks before field planting on raised beds covered with single use, polyethylene black plastic mulch in April 2019, and covered with low tunnels, two weeks after field planting. The trial was set up with four replicates for three day-neutral cultivars in a split plot design, and the following treatments: plants grown under a) solid 4-mil plastic, b) slitted 0.8-mil plastic and c) in open field conditions (control). The field was fertilized with 68 lbs of N pre-planting and then fertigated through the drip irrigation every 1.5 weeks for a total of 130 lbs N applied for the season. Plants are being managed using certified organic production practices. Yield, leaf tissue and soil nutrient concentration, leaf, crown and runner biomass are being collected. Preliminary results from the 2019 trial, show that late-season marketable yield was greater under solid and slitted tunnel treatments compared to open beds (44.3, 17.4, and 2.5g/plant, respectively; $P<0.001$). The 2020 season is ongoing, and data collection and analysis continue.

Strawberry transplant production for early and late production in Oregon: effects of container size on cost, ease of planting and plant development (study in progress)

Javier Fernandez-Salvador, Erica Chernoh, Tessa Barker (graduate student) and Steve Tao (undergraduate student), Oregon State University.

The objective of this study is to determine the optimal size of transplant container for ease of planting and reduced production costs, without affecting plant development for applications in field and in substrate day neutral strawberry production systems. This two year (2018-2019) study was conducted at the OSU North Willamette Research and

Extension Center. Two cultivars, ‘Albion’ and ‘Seascape’ were grown in organically approved planting media (tree bark byproducts, peat-moss, pumice and feather meal fertilizer) in two container sizes (234 cm^3 and 614 cm^3). Bare-root strawberry plants were potted into containers in early March and kept in an unheated greenhouse. Plant growth and development was measured every week including leaf area, crown number and width, as well as mortality, and before field planting root and complete plant biomass were determined in a subsample of the treatments. In the spring of 2019, the plugs were planted into the field, along with bare-root plants (control) for comparison, in a split plot design with six replicates. Plant biomass, crown diameter, and yield (marketable, cull and total yield) data were collected from the field experiment over the course of 16 weeks. In 2018, ‘Seascape” and large container sized plants produced the highest marketable and total yields compared to ‘Albion’ and small container plants. In 2019, ‘Seascape’ once again produced higher yields compared to ‘Albion’, however, the bare-root plants produced the greatest marketable and total yields compared to large and small container plants.

Substrate strawberry production systems for fresh market in greenhouse elevated benches (preliminary study)

Javier Fernandez-Salvador, Erica Chernoh, Avery Pheil Oregon State University.

This project will expand upon the fresh market, day neutral strawberry production research currently underway at OSU NWREC, by exploring elevated bench, substrate greenhouse production systems. While fresh organic strawberries can be profitable for growers, their production is labor intensive, requiring frequent weeding and application of pesticides and hand harvest at ground level. Elevated substrate systems in greenhouses or tunnels could reduce labor and resource costs over multiple seasons, by cutting down on pest pressure, and making plants more easily accessible for fast and efficient management and harvest. The goal of this project is to conduct a preliminary study on bench substrate technologies that may improve efficiencies and yields in Oregon strawberries. This preliminary study will explore the feasibility and equipment needs for two different system designs, evaluate different planting media combinations, determine best practices for fertilizer use, and determine overall equipment and labor costs for elevated substrate production of strawberries under greenhouse cover in Oregon.

Current state of the strawberry industry in Oregon and grower needs assessment survey (in progress)

Javier Fernandez-Salvador, Erica Chernoh, and Cora Bobo-Shisler, Oregon State University.

A needs assessment survey was conducted to examine the current state and needs of the strawberry industry in Oregon. The objectives of this project are to guide future research, improve collaboration between extension, industry, and growers, in order to meet producer needs. The comprehensive study contains questions about farming practices (production, cultivars, irrigation, season extension, and pest management), grower needs and challenges, as well as services provided by extension, and grower interest in future

research. This project will provide valuable information to OSU Extension Service to guide future programing, in addition to establishing a means to connect with growers for collaboration and upcoming research, including a Strawberry Fertility and Nutrient survey by the Principal Investigator, Javier Fernandez-Salvador. The first stage of the survey has been completed and data is being analyzed. A follow-up study is being planned to present results and gather further information for the strawberry industry. Results from the survey show that *Botrytis cinerea*, slugs, voles and Spotted Wing Drosophila to be the most problematic pests for growers. Survey respondents reported labor cost and availability and pest management to be their greatest challenges; with pest management, cultivar development, and nutrient management to be the most pressing research needs. Due to COVID-19, the focus group meetings have been postponed to 2021.

The relationship between fertilization practices, soil and plant nutrient status and yield in strawberry cultivars (in progress)

Javier Fernandez-Salvador, Avery Pheil, Erica Chernoh. Oregon State University

A fertility survey is being conducted with strawberry growers in Oregon to better understand the impacts of the varying practices used on yield. This information will be gathered to better inform new research and extension programs on nutrient and fertilizer management in the state. The study goal is to help the strawberry industry increase the efficiency of fertilizer programs leading to benefits including minimizing input and costs while maximizing productivity thus increasing the economic viability of strawberry farmers. The objective of the research is to work with commercial growers of widely grown strawberry cultivars in Oregon to determine their current and previous year fertilizer management practices, collect yield data, and sample tissue (fruit and leaf nutrient concentration), and soil nutrients at each of these collaborator sites. This study will help us define the relationship between fertilizer application practices and yield, soil and plant nutrient status by cultivar. In 2019, 31 fields across 17 grower sites were sampled. Soil analyses showed that 29% of the fields sampled met the standards for strawberries for soil nutrients, pH and organic matter. Nearly two-thirds of fields with June-bearing cultivars had a high or low soil pH, almost half of the day-neutral fields had a high pH. Leaf tissue sampling indicated that nearly half of the sampled fields were above or below essential nutrients sufficiency ranges. Boron deficiency was most common, found in 25 of the 31 sampled fields. Results of the study show that Oregon specific nutrient management guidelines, particularly for day-neutral cultivars, could be improved.

Grapes

Statewide Crop Load Project: Defining Yield Management Practices for Quality Pinot noir in Oregon

Patricia A. Skinkis*, Department of Horticulture, Oregon State University, Corvallis, OR, James Osborne* and Elizabeth Tomasino*, Department of Food Science & Technology, Oregon State University, Corvallis, OR, Katherine McLaughlin, Oregon State University, Corvallis, R. Paul Schreiner*, USDA-ARS, Corvallis, OR, Amelia Doyle, Department of Horticulture, Oregon State University. *member of the Oregon Wine Research Institute at Oregon State University

Crop thinning is conducted in the majority of Pinot noir vineyards in Oregon, as it is thought to ensure premium quality fruit and hasten ripening in the cool climate regions of the state. The industry-wide yield target for Pinot noir has been 2 to 2.75 tons/acre. However, these targets are not scientifically-founded yet are universally applied across Oregon vineyards, regardless of vineyard productivity, vine density, or seasonal heat units. Furthermore, there are no vine balance metrics by which to evaluate the yield-quality relationship, and metrics defined by other crop level studies from different regions have not worked nor have elicited change in this strong-held belief that low yield equals high quality. To develop better yield management guidelines for industry, a long-term industry collaborative research project has been in progress since 2012. To date, 22 industry collaborators participated in the research. Each collaborator applied two or more crop levels by cluster thinning replicated plots within commercial Pinot noir vineyards during lag-phase of berry development. Vineyard data was collected by the collaborator (according to protocols designed by OSU), including fruitfulness, cluster and shoot counts, véraison tissue analysis for macro- and micro-nutrients, yields, and pruning weight. Fruit samples at harvest were analyzed for basic ripeness parameters as well as various acids, fermentable nitrogen, anthocyanins, and phenolic compounds. Wines were produced by each participating winery using 1.5 tons of each crop level. Wines were evaluated by a winemaker sensory panel after 2 years of bottle-aging. Crop levels ranged from 0.4 to 1.5 kg/m in 2012 and 2013, 0.7 to 1.9 kg/m in 2014, 0.8 to 2.7 kg/m in 2015, 0.6 to 1.6 kg/m in 2016, 0.8 to 2.8 kg/m in 2017, 0.9 to 2.1 kg/m in 2018, and 0.7 to 1.87 kg/m in 2019. Despite multiple years of cropping at high or low levels, there was no effect of yield on dormant pruning weight or vine nutrient status in most vineyards. After eight years, there are no signs of vineyards being over-cropped and all could physiologically handle the levels of fruit in the full crop treatments. Fruit composition at harvest did not differ by cluster thinning within 15-45% of sites each year. For the remaining 67-85% of sites, there were few consistent differences. In fact, there were some of the fewest differences by crop level in the highest yielding years (2015 and 2017). However, anthocyanin concentration increased by reduced yields in 20% of sites across the eight-year period. Sensory evaluation of 2012-2016 wines show that yield does not affect wine characteristics (mouthfeel, aroma, etc.). In-house sensory evaluations of trial wines by the wineries (blind tastings) show that winery staff can determine differences in the wines (difference testing) but quality rankings are not consistent and are not always linear (lowest yield was not always highest wine quality ranking). This project continued in 2020 despite the challenges of COVID-19, and as of this reporting

12 of 13 vineyards have submitted harvest data and samples. One additional growing seasons remains for this project in 2021. This long-term data set will be used to develop yield management guidelines that are suited to different climates, years and winery production targets (bottle prices). Two manuscripts are published from the study, focusing on the yield management practices and methods for developing an industry-citizen science project. Two other manuscripts are in progress for quantitative results for the first 5 years of the study.

Improving cool climate vineyard yield potential through pruning and nitrogen fertilization practices

Patricia A. Skinkis,* Department of Horticulture, Oregon State University, Corvallis, OR, Miranda Ulmer (graduate student), Department of Horticulture, Oregon State University, Corvallis, OR, and R. Paul Schreiner*, USDA-ARS Horticulture Crops Research Lab, Corvallis, OR, all of the Oregon Wine Research Institute at OSU. *member of the Oregon Wine Research Institute at OSU

Pinot noir is a low yielding variety compared to other *Vitis vinifera* wine grape varieties, and prior cultivar trials show that Oregon yields are lower than California for the same Pinot noir clones. Yield consistency is a concern for growers, and we believe that vineyard practices, including dormant pruning and nitrogen (N) management, could alter vineyard yield potential. The majority of Oregon producer use cane pruning, but they are interested in spur pruning because it can be partially mechanized. Prior research in the Skinkis lab shows that Pinot noir basal buds are fruitful and may result in sufficient yields with spur pruning, but it had not been tested until this study. Nitrogen is integral to grapevine growth, floral development and yield. Vegetative vigor and fruitfulness have been shown to be limited by low vine N status. It is common for vineyard managers to avoid N fertilization to prevent vigorous canopies. However, low yields and low berry N may limit quality production. In order to understand the effect of dormant pruning methods and nitrogen fertilization in vineyard productivity, separate field experiments took place from 2017-2019. The pruning trial compared spur and cane pruned vines in a high density vineyard. The nitrogen trial compared N-fertigated vines (60 lb. N/acre in 3 split applications). For each trial, we measured fruitfulness of dormant buds, shoot fruitfulness in-season, fruit set, canopy growth, yield, and pruning weights. The pruning trial revealed that the basal buds are fruitful regardless of pruning method with similar number of inflorescences for the same nodes (1-5). The mean number of inflorescence primordia per bud and the sizes of the inflorescence primordia were similar in cane and spur pruned vines when considering all buds assessed. Furthermore, there was no difference in fruitfulness observed post-bud break. There was no difference in timing of bud break or phenological advancement during the season and no difference in canopy growth. Spur pruned vines had slightly more leaf area and pruning weights but both cane and spur had similar yield to pruning weight ratios. Spur pruned vines have slightly smaller clusters compared to cane pruned vines, but yields were not difference by harvest. The N project shows no differences in the bud fruitfulness or fruitfulness post-budbreak. There were differences in shoot growth but they were minimal, and the impact was not significant enough to cause dormant pruning weights to differ. The lack of vine response to N application suggest that either not enough N was applied to increase

fruitfulness and yield or that the vines had sufficient N resources that further applications did not illicit a physical growth response. Future work will be conducted to explore N application to increase yield uniformity in non-uniform vineyards. Both experiments show that bud fruitfulness is higher in canes that are more vigorous. This suggests that increasing vine vegetative growth and vigor is not detrimental to Pinot noir productivity. This project has been completed and one manuscript was published in June 2020 with another publication in progress.

Understanding symptomology and physiological effects of Red Blotch Disease in vineyards in Oregon's Willamette Valley

Patricia A. Skinkis*, Department of Horticulture, Oregon State University, Corvallis, OR, Justin Litwin (graduate student), Department of Horticulture, Oregon State University, Bob Martin*, USDA-ARS Horticulture Crops Research Lab. *member of the Oregon Wine Research Institute at OSU

Grapevine Red Blotch Disease has become a major concern for winegrape producers in Oregon and other areas of the US. The disease was identified as Grapevine Red Blotch Virus (GRBV) in 2012. The virus results in symptoms that may severely affect fruit and wine quality and lead to non-economic production. The lack of fruit ripening is a major concern for cool climate regions such as the Willamette Valley where heat units limit the growing season and Pinot noir and other cultivars grown in the region may struggle to reach optimum ripeness in a typical year. As we seek to provide management options for growers, we need information about how this virus may be affecting vine growth, development and fruit ripening. We designed a multi-year study to evaluate the impacts of Grapevine Red Blotch Virus on grapevines in two Pinot noir vineyards in the Willamette Valley. We monitored vine growth, photoassimilation, water status, vine nutrient status, and fruit composition of GRBV+ and GRBV- vines within the same block in two vineyards from 2017-2019. Results varied by vineyard, with one of the sites, Vineyard A, having limited impact on vine water status, leaf photoassimilation, nutrient status, or vine growth based on virus status. In addition, we found no differences in fruit ripeness (Brix, pH, and titratable acidity) or total phenolics, tannins or anthocyanins at Vineyard A. However, there were more differences found in Vineyard B, which had greater intensity of visual symptoms in GRBV+ vines. There was lower photoassimilation and stomatal conductance in basal leaves of GRBV+ vines and vines showing symptoms for the latest sample near harvest. There were no differences in photoassimilation and stomatal conductance of any mid-upper canopy leaves on any of the three late season dates. Vineyard B originally was thought to have both virused and healthy vines, but after further testing revealed that there was 100% virus infected vines. From this vineyard we were able to determine that GRBV+ vines can be asymptomatic, and by the second year of the study, nearly all vines showed no symptoms due to management changes to remove vine stress. The graduate student on this project completed his MS degree program in June 2020. One manuscript is in progress.

Exploring vineyard management practices to mitigate effects of Red Blotch Disease in Oregon's Willamette Valley

Patricia A. Skinkis*, Department of Horticulture, Oregon State University, Corvallis, OR, Justin Litwin (graduate student), Department of Horticulture, Oregon State University, Bob Martin*, USDA-ARS Horticulture Crops Research Lab, James Osborne*, Department of Food Science & Technology, and Alexander Levin*, Department of Horticulture, Oregon State University – Southern Oregon Research & Extension Center, *member of the Oregon Wine Research Institute at OSU

Grapevine red blotch disease (GRBD), a recently identified virus, has reported to reduce fruit and wine quality of wine grapes in the US. Some Oregon producers report reduced wine quality, as infected vines have led to wines that do not meet sensory acceptance during blending to be included in their luxury tier wines. As a result, we designed two management trials to evaluate the effect of vineyard management practices on a commercial GRBD infected vineyard reported to have suffered wine quality impacts. In separate experiments, we tested the impacts of early season leaf removal (pre-bloom and at fruit set) and the application of abscisic acid (ABA) during veraison, as both practices have been shown to impact fruit phenolic development in other vineyard studies. The trials were carried out during the 2018 and 2019 growing seasons. The leaf removal trial included a comparison of three leaf removal treatments, including 100% cluster zone leaf removal by hand just before bloom, leaf removal by machine to the eastern exposure of the canopy cluster zone by machine at fruit set, and leaf removal by machine at fruit set of the east and west sides of the cluster zone. The ABA trial included vines sprayed with Protone in the cluster zone (beginning of veraison and again 2 weeks later). The cluster zone leaf removal 2018 results shows that yields were not affected. However, cluster size was smaller for the early leaf removal treatment compared to the later mechanical leaf removal. However, there were no differences in clusters per vine or berries per cluster. There was not sun burning on the early leaf removal treatment despite full exposure of the clusters. There was no difference in Brix, pH, or TA at harvest in either year. There were no differences in anothcyanin, phenolics, or tannins as result of these treatments in either year, but the wine analysis that was conducted indicates more intense wine color in 2018. For the ABA trial, application to the clusters did not enhance ripening, as there was no differences in primary ripeness (total soluble solids, pH, titratable acidity) or phenolics (total anthocyanin, tannin, or phenolics) with the unsprayed control. The viticulture components of this study were completed in winter 2020, but fruit and wine analysis by colleagues in the Food Science and Technology Department at Oregon State University continues in 2020.

Characterizing Willamette Valley Soil Moisture and Grapevine Response under Drying Seasonal Conditions

Patricia A. Skinkis, Department of Horticulture, Oregon State University, Corvallis, OR, R. Paul Schreiner, USDA-ARS Horticulture Crops Research Lab, both members of the Oregon Wine Research Institute at OSU

Willamette Valley vineyards experience late season water stress that may be limiting vine growth and production, depending on soil type and season. There is a need for producers

to understand how to manage vineyard soil water, whether through irrigation or vineyard floor management. During this three-year project, we are monitoring soil moisture and Pinot noir grapevine growth, water stress, and fruit development and composition across three soil types. This work is underway in a commercial vineyard comprised of three soil types that are common to Willamette Valley wine grape vineyards, including a sedimentary soil, volcanic soil, and marine sediment soil. The project began with soil moisture installation in January 2020 and soil moisture and temperature data were logged continuously since that time. Plant growth data, phenology, and fruit samples were collected in the 2020 growing season and await statistical analyses and laboratory analyses, respectively. Information will be useful to regional growers to understand soil moisture management and will lead to regional vine vineyard floor and vine balance guidelines based on soil and productivity potential.

Rootstock effects on mature Pinot noir growth and productivity under cool climate, dry-farmed conditions

Patricia A. Skinkis, Department of Horticulture, Oregon State University, Corvallis, OR,

The Oregon wine grape industry has experienced warmer, drier summers over the past decade. The first grafted vineyards were planted to three vigor reducing rootstocks (101-14, 3309 and Riparia Gloire). However, with increasingly drier growing seasons in recent years, growers question the suitability of these rootstocks for the Willamette Valley, and there is great interest in understanding how rootstocks can be selected to help determine suitability for dry-farming and/or optimizing irrigation water in the region. Over three growing seasons, we are evaluating an established OSU rootstock trial (planted in 1997), with focus on Pinot noir growth response on 19 rootstocks and compared to own-rooted vines. We are monitoring phenological advancement, yield, basic fruit ripeness, yeast assimilable nitrogen (YAN), anthocyanins and phenolics of fruit. The project began with preliminary data collection in 2019 with the full set of data collection beginning in 2020 after successful funding from the Oregon industry. The project has been harvested just days before this reporting, and the data and fruit samples are pending analysis. Findings from this research will help growers make new vineyard plant material selections, by allowing them to consider the performance of varied rootstocks locally and under dry-farmed conditions.

Re-evaluating pressure chamber methods of water status determination in field-grown grapevine (Vitis spp.) **Completed**

Alexander Levin*, Assistant Professor, Department of Horticulture, Southern Oregon Research and Extension Center, Oregon State University; *member of the Oregon Wine Research Institute at OSU

Despite the fact that the pressure chamber has been used as a tool to assess vine water status and assist in scheduling vineyard irrigation for more than 30 years, there remains some disagreement in sampling protocol with respect to midday leaf water potential (Ψ_{leaf}) and midday stem water potential (Ψ_{stem}) determination. Therefore, the primary goal

of this study was to test various sampling protocols associated with the measurement of these two variables. Specifically, experiments were conducted to test the effects of (1) re-cutting the petiole prior to placing the leaf in the chamber, (2) time span between sample excision and pressurization, (3) sample equilibration time on Ψ_{stem} values, and (4) the effect of operator. Results showed that there was no significant effect of re-cutting the petiole on Ψ_{leaf} values. Furthermore, up to 30 seconds of time span between sample excision and pressurization was acceptable for accurate Ψ_{leaf} determinations, as long as the sample was kept shaded during that time. Finally, only 10 minutes of equilibration time was necessary for accurate Ψ_{stem} determination. In most cases, the effect of operator on all Ψ determinations was greater than any of the sample preparation methods tested. This reinforces the need to properly train vineyard technicians in using the pressure chamber. However, improved flexibility in sampling protocol for either Ψ_{leaf} or Ψ_{stem} determinations may improve efficiency of vine water status monitoring in vineyards, thus reducing labor costs associated with pressure chamber-based irrigation scheduling.

Data driven models for canopy temperature- based irrigation scheduling **Completed**

Bradley A. King, Agricultural Engineer, USDA-ARS Northwest Irrigation and Soils Research; Krista C. Shellie, Research Horticulturist, USDA-ARS; David D. Tarkalson, Research Soil Scientist, USDA-ARS Horticultural Crops Research; Alexander Levin*, Assistant Professor, Department of Horticulture, Southern Oregon Research and Extension Center, Oregon State University; Vivek Sharma, Assistant Professor, Precision Water Management, Department of Agricultural and Biological Engineering, University of Florida, Institute of Food and Agricultural Sciences; David L. Bjorneberg, Supervisory Agricultural Engineer, USDA-ARS Northwest Irrigation and Soils Research; *member of the Oregon Wine Research Institute at OSU

Normalized crop canopy temperature, termed crop water stress index (CWSI), was proposed over 40 years ago as an irrigation management tool but has experienced limited adoption in production agriculture. Development of generalized crop-specific upper and lower reference temperature is critical for implementation of CWSI-based irrigation scheduling. The objective of this study was to develop and evaluate data driven models for predicting reference canopy temperatures needed to compute CWSI for sugarbeet and wine grape. Reference canopy temperatures for sugarbeet and wine grape were predicted using machine learning and regression models developed from measured canopy temperatures of sugarbeet, grown in Idaho and Wyoming, and wine grape, grown in Idaho and Oregon, over 5 years under full and severe deficit irrigation. Lower reference temperatures (T_{LL}) were estimated using neural network models with Nash-Sutcliffe model efficiencies exceeding 0.88 and root mean square error less than 1.1 °C. The relationship between T_{LL} minus ambient air temperature and vapor pressure deficit was represented by a linear model that maximized the regression coefficient rather than minimized the sum of squared error. The linear models were used to estimate upper reference temperatures that were nearly double values reported in previous studies. A daily CWSI, calculated as the average of 15-min CWSI values between 13:00 and 16:00 MDT for sugarbeet and 13:00 and 15:00 local time for wine grape, were well correlated with irrigation events and amounts. There was a significant ($p<0.001$) linear relationship

between the daily CWSI and midday leaf water potential of Malbec and Syrah wine grape with an R^2 of 0.53. The data driven models developed in this study to estimate reference temperatures enable automated calculation of the CWSI for effective assessment of crop water stress. However, measurements taken under conditions of wet canopy or low solar radiation should be disregarded as they can result in irrational values of the CWSI.

Water deficits do not improve fruit quality in Grapevine Red Blotch Virus-infected grapevines (Vitis vinifera L.) **Completed**

Alexander Levin*, Assistant Professor, Department of Horticulture, Southern Oregon Research and Extension Center, Oregon State University; Achala KC, Assistant Professor, Department of Botany and Plant Pathology, Southern Oregon Research and Extension Center, Oregon State University; *member of the Oregon Wine Research Institute at OSU

Although deficit irrigation is used to improve fruit quality in healthy grapevines, it can potentially amplify negative effects of viral disease and reduce fruit quality in Grapevine Red Blotch Virus (GRBV) infected grapevines. Therefore, a two-year field experiment was conducted to understand the interaction between GRBV infection and water deficits on disease development and vine physiology. Well-watered (WW) vines were irrigated at 100% of estimated crop evapotranspiration (ET_c), while water deficit (WD) vines received water at 66 and 50% ET_c in 2017 and 2018, respectively. Healthy (GRBV-) and infected (GRBV+) vines were confirmed by PCR assays. There were no significant effects of water deficits on foliar symptom onset in either year, but more severe water deficits in 2018 resulted in a more rapid symptom progression. GRBV+ vines had a higher Ψ_{stem} compared to GRBV-vines, but the effects of virus only appeared post-veraison and corresponded to decreased leaf gas exchange. In general, vine vegetative and reproductive growth were not reduced in GRBV+ vines. Yields were highest in WW/GRBV+ vines due to larger clusters containing larger berries. Consistent treatment effects on berry primary chemistry were limited to sugars, with no interactions between factors. Water deficits were able to somewhat increase berry anthocyanin concentration in GRBV+ fruit, but the effects were dependent on year. By comparison, virus status and water deficits interacted on skin tannins concentration such that they were decreased in WD/GRBV+ vines, but increased in WD/GRBV- vines. Water deficits had no effect on seed phenolics, with only virus status having a significant diminution. Although keeping GRBV+ vines well-watered may mitigate some of the negative effects of GRBD, these results suggest that water deficits will not improve overall fruit quality in GRBV+ vines. Ultimately, the control of fruit ripening imparted by GRBV infection seems to be stronger than abiotic control imparted by water deficits.

Efficacy of cultural practices for mitigating negative effects of Grapevine Red Blotch Disease in Oregon Pinot noir **In progress**

Cody Copp (graduate student), Department of Horticulture, Oregon State University; Achala KC, Assistant Professor, Department of Botany and Plant Pathology, Southern Oregon Research and Extension Center, Oregon State University; and Alexander Levin*, Assistant Professor,

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Grapevine Red Blotch Disease (GRBD) has been reported to impact vine physiology and fruit quality in *Vitis vinifera* L. by reducing photosynthetic rate, total soluble solids (TSS), and berry anthocyanin concentration. Currently, growers have few management strategies beyond removal of infected vines, which is particularly costly in young vineyards with high disease incidence. Two studies were established in 2018 and 2019 in commercial Pinot noir vineyards in Southern Oregon. Study A comprises a field survey to further characterize the impact and chronology of GRBD symptoms. Study B is a field trial which investigates the potential of cultural practices (irrigation, fertilization, crop load management) to mitigate the negative effects of the disease on vine physiology and fruit quality. Doubled rates (supplemental) of irrigation and fertilizer were compared against a grower control while crop load management compared thinning (one cluster per shoot) against no thinning. In Study A, GRBD reduced the rate of photosynthesis and stomatal conductance while increasing stem water potential and the leaf concentration of nonstructural carbohydrates. TSS, anthocyanins, and seed phenolics were significantly lower in mature fruit from infected vines. Study A largely confirms the impacts of GRBD reported in other studies but advances the understanding of the chronology of symptoms which may begin with an increase in leaf sugar concentration. The increase in leaf sugar appears to subsequently downregulate photosynthesis and thus induce foliar reddening, close stomates, and raise stem water potential. In Study B, supplemental irrigation significantly reduced disease severity (red leaves per vine) over two years, while supplemental fertilization had no significant effect and, in the second year (2019), thinning significantly increased severity. Supplemental irrigation and crop thinning significantly impacted vine physiology and fruit composition in 2019, but fertilization had no significant effect over two years. Photosynthetic rate, berry weight, and TSS were increased by supplemental irrigation. Supplemental irrigation did not have consistently significant effects on secondary metabolites, but most often reduced anthocyanins and skin phenolics and increased seed phenolics. Crop thinning significantly increased berry weight, pH, and some secondary metabolite concentrations in berry skin. Irrespective of applied water amounts, maintaining a high vine water status was shown to be useful for directly counteracting many of the symptoms observed in Study A. Ultimately, these results suggest that routine viticultural practices such as irrigation and crop thinning have the potential to mitigate the negative effects of GRBD on vine physiology and fruit composition.

Response of fruit growth and composition of Vitis vinifera L. cv. Pinot noir to pre-and postveraison water deficits in a warm climate **In progress**

Cody Copp (graduate student), Department of Horticulture, Oregon State University; Alexander Levin*, Assistant Professor, Department of Horticulture, Southern Oregon Research and Extension Center, Oregon State University; *member of the Oregon Wine Research Institute at OSU

Deficit irrigation is used in wine grape production to achieve fruit quality goals like advancing ripening and increasing concentrations of phenolic compounds. The response of *Vitis vinifera* cv. Pinot noir to deficit irrigation is not well documented in the literature and is critical for warm, dry regions as well as cool winegrowing regions with warming climates. The objective of this study was to observe vine and fruit responses to early and late season water deficits and identify water status targets to guide irrigation scheduling. Irrigation treatments consisted of combinations of pre- and postveraison irrigation levels as fractions (100, 75, 50 and 25%) of estimated crop evapotranspiration (ET_c). Vine water status exhibited a strong positive relationship with applied irrigation in both years of the study, with more variation between years preveraison. Preveraison water deficits decreased berry mass and slightly reduced fruit yield. Total soluble solid (TSS) concentrations did not respond consistently to pre- or postveraison water status, though there is some evidence of a positive relationship between preveraison water status and TSS at harvest. Concentrations of phenolics (anthocyanins, tannins, iron-reactive-phenolics) exhibited a negative relationship with preveraison vine water status; the response was stronger in skin-associated phenolics, suggesting that the effect is linked to berry size. Postveraison water deficits also impacted phenolics, but the relationship was nonlinear and phenolics peaked at moderate water deficits (e.g. 75 and 50% of ET_c). TSS, berry mass, and yield were not sensitive to postveraison water deficits. Preveraison water deficits increased phenolics linearly, but the effects are unknown beyond stem water potentials of -1.4 MPa, below which was not observed in this study. Preveraison, ET_c-based irrigation requires frequent monitoring of vine water status due to the increased variability in response to irrigation. Postveraison water status values in the range of -0.9 to -0.5 MPa optimized phenolics concentrations, though this study did not observe the effect of postveraison water deficits below -1.3 MPa. Overall, postveraison water deficits appear to offer fewer benefits relative to preveraison deficits, but also pose fewer consequences and can be more consistently imposed with ET_c-based irrigation. Ultimately, preveraison water deficits may improve fruit quality, especially in production systems where yield is manipulated and attaining target TSS is not of concern.

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Impact (Objective 2):

Blueberries

(Strik et al.) In organic blueberries, the common use of fertilizer sources with high K has increased leaf and soil nutrient levels reducing yield (published papers). The goal of our continuing research is to provide growers with important information on how quickly changing fertilizer practices may adjust soil and plant nutrient status and impact yield. Some changes, such as a reduction in soil K have been relatively rapid and positive for plant health. Yield has increased across all treatments in 3 of the 4 growing seasons since switching fertilizer and mulch systems.

(Strik et al.) Weed mat. Our recently published study on development of 10 cultivars from planting to maturity in two certified organic mulching/amendment systems illustrated the

importance of mulch type and the possibility of mitigating a measured decline in soil organic matter under weed mat by adding a sawdust mulch layer underneath. Building upon what was learned in this long-term study, we initiated a new study with a goal of better understanding the relationships between mulching practices, soil properties and characteristics, and plant growth and establishment in blueberry. We have determined that the addition of sawdust under weed mat may justify the extra production cost through improved plant growth during establishment, and increased yield in the first production year, along with reduced soil temperatures and vole presence. While the addition of sawdust mulch under weed mat does not rapidly increase soil organic matter, it may help mitigate the long-term losses we saw in past research. Since weed mat color did not have an impact on plant growth, we recommend continuing to use the industry standard and widely available black weed mat. Overall impacts of mulch on fruit quality across three years of study were minor, and fruiting season was not affected despite differences in soil temperature under the mulches and canopy temperature in the first season.

(Strik et al.) With reduced labor availability and higher labor costs, we are in the process of developing a reduced labor production system for 'Mini Blues' blueberry. Leaving 'Mini Blues' unpruned for 3 years has not resulted in lower yield or any loss in fruit quality. Berries from unpruned plants have been slightly smaller but not to the extent that it would be detrimental for this already small-fruited cultivar; over time we expect they will continue to reduce in size indicating the plants need renovating. Considering this technique required 90% less time than the standard method to prune, a huge cost savings for growers, we feel this could be a successful production practice. Work is on-going.

(Strik et al.) After 3 years of implementing different pruning and trellising techniques, yield in 'Legacy' was improved in 2020 using the revised pruning technique recommended by Dr. Strik compared to typical northern highbush style pruning. Fruit quality has not been impacted, and we expect to continue to see differences in yield as work continues for one more year.

Grapes

(Skinkis; crop load) Cluster thinning has less impact on fruit and wine quality than vineyard site, and it is not consistent in achieving certain fruit quality parameters between years or sites. Through active engagement in this research, vineyard managers and winemakers have learned how to implement research on their site and how to utilize data collection protocols. Many of them report having a greater understanding of the whole vineyard system, are much more observant in the vineyard, and are beginning to look at yield management differently. Project collaborators have confidently increased yields by 0.5 ton per acre annually without compromising quality. This has led to a 25% increase in yields, which can harness an additional $1500/acre in grape sales on average (across the 17,744 bearing Pinot noir acres in the state), resulting in additional $2.3 million per year in farm gate value for Pinot noir grapes. Many collaborators also said that the increased yield is leading to more volume of quality wine (with no reduction in bottle price), as they have not seen a reduction in fruit or wine quality with yield increases between 0.5-1.0 tons per acre.

(Skinkis; yield potential through pruning and fertilization) Spur pruning is possible without causing loss in yield, fruit ripening, or fruit composition at harvest. This will allow growers to

consider using spur pruning and apply partial mechanization in vineyards to reduce labor costs during pruning. Selecting larger canes at pruning can also allow for greater vine fruitfulness and yield potential. Further work is needed to understand N fertilization practices to enhance yield uniformity in vineyards. This was part of a MS thesis for the graduate student on the project. The research has been published in one peer refereed journal article as of June 2020.

(Skinkis; red blotch) The multi-year and multi-site data suggest that certain vineyards are not impacted greatly by the virus (growth or fruit composition), and vines respond differently by season, possibly due to soil type, vineyard health, and seasonal climatic conditions. It is possible that growers can maintain vineyard blocks rather than removing them merely based on virus infection status. This was part of a MS thesis for the graduate student on the project; the student successfully completed his degree in June 2020.

(Levin et al.; Red Blotch) The first published work documenting effects of Grapevine Red Blotch Disease (GRBD) in Oregon simultaneously confirms, but also extends much of the initial work conducted in California. Many of the previously reported symptoms of GRBD on fruit quality (e.g. reduced berry total soluble solids and anthocyanin concentration) were shown to hold true in a new region (Southern Oregon) and with a different cultivar (Pinot noir) – underscoring the seriousness of the disease. However, our study documented – for the first time – the complex interactions between abiotic stress (i.e. water deficits) and biotic stress (i.e. viral infection). For most factors, these two stressors impacted grapevine physiology independently – in other words did not interact – but for several important berry secondary metabolites imposition of water deficits in the context of GRBD further reduced fruit quality. Supplementary work (that is still in progress) is examining cultural practices that are aimed at reducing plant stress. Early results from this work have been presented at several conferences and grower meetings, and to a large degree, confirm that reduction of abiotic stress can improve – or at the very least mitigate – some of the negative symptoms associated with GRBD. Producers now have a better understanding of GRBD effects on grapevine physiology, and how to manage vineyards in lieu of costly replanting.

(Levin et al.; Water deficits/irrigation management) Significant efforts have been made to validate decades of vineyard irrigation management research conducted in California to the rapidly expanding Southern Oregon grape growing area. Research studies have been conducted to 1) confirm/validate existing technologies used for plant water stress monitoring and irrigation scheduling; 2) develop new, more automated technologies for plant water stress monitoring and irrigation scheduling; and 3) understand responses of Pinot noir cultivar to water deficits. In addition to applied research work, substantial outreach has been ongoing to educate producers on proper irrigation management. Thus far, early results from research have streamlined existing monitoring technologies, and validated existing models regarding new technologies, ultimately reducing associated production costs. Existing regional irrigation scheduling service networks (e.g. AgriMet) have also been shown to greatly overestimate vineyard water requirements, and though this work is ongoing, results indicate that growers could reduce water use by up to 50% with little no drop in productivity. Finally, outreach efforts have resulted in increased sales of plant water stress monitoring equipment, suggesting that wine grape growers are taking a more active role in irrigation management, a practice that will likely lead to continued reduction in vineyard water use.

Papers (published since September 2019) – Objective 2

Refereed papers:

Finn, C.E., **B.C. Strik**, B.M. Yorgey, M.E. Peterson, P.A. Jones, J. Lee, N. Bassil, and R.R. Martin. 2020. 'Twilight' thornless semi-erect blackberry. HortScience 55:1148-1152.

Finn, C.E., **B.C. Strik**, B.M. Yorgey, M.E. Peterson, P.A. Jones[+], Gil Buller[+], J. Lee, N. Bassil, and R.R. Martin. 2020. 'Galaxy' thornless semi-erect blackberry. HortScience 55:967-971.

Finn, C.E., **B.C. Strik**, B.M. Yorgey, M.E. Peterson, P.A. Jones, Gil Buller, S. Serce, J. Lee, N. Bassil, and R.R. Martin. 2020. 'Eclipse' thornless semi-erect blackberry. HortScience 55:749-754.

King, B.A., K.C. Shellie, D.D. Tarkalson, **A.D. Levin**, V. Sharma, D.L. Bjorneberg. *In press*. Data Driven Models for Canopy Temperature Based Irrigation Scheduling. Applied Engineering in Agriculture.

Kingston, P.H., C.F. Scagel, D.R. Bryla, and **B.C. Strik**. 2020. Effect of perlite in peat- and coir-based media on vegetative growth and mineral nutrition of highbush blueberry. HortScience 55:658-663.

Levin, A.D., A.N. KC. 2020. Water deficits do not improve fruit quality in Grapevine Red Blotch Virus-infected grapevines. Frontiers in Plant Science 11:1292.

Levin, A.D., A. Deloire, G.A. Gambetta. 2020. Does water deficit negatively impact wine grape yield over the long term? International Viticulture and Enology Society: Technical Reviews.

Levin, A.D., M.A. Matthews, L.E. Williams. 2020. Effect of Preveraison Water Deficits on the Yield Components of 15 Winegrape Cultivars. American Journal of Enology and Viticulture 71(3):208-221.

Levin, A.D. 2020. Improvement of pressure chamber protocols - Response to Hochberg (2019). Agricultural Water Management 227.

Levin, A.D., L.E. Williams, M.A. Matthews. 2019. Continuum of stomatal responses to water deficits among 17 wine grape cultivars (*Vitis vinifera* L.). Functional Plant Biology 47(1):11-25.

Levin, A.D. 2019. Re-evaluating pressure chamber methods of water status determination in field-grown grapevine (*Vitis spp.*). Agricultural Water Management 221:422-429.

Sales, B.K., D.R. Bryla, K.M. Trippe, J.E. Weiland, C.F. Scagel, and **B.C. Strik**. 2020. Amending sandy soil with wood biochar promotes plant growth and root colonization by mycorrhizal fungi in highbush blueberry. HortScience 55:353-361.

Strik, B.C., A.J. Davis, and D.R. Bryla. 2020. Individual and combined use of sawdust and weed mat mulch in a new planting of northern highbush blueberry I. Impacts on plant growth and soil and canopy temperature. HortScience 55:1280-1287.

Strik, B.C., A.J. Davis, and D.R. Bryla. 2020. Individual and combined use of sawdust and weed mat mulch in a new planting of northern highbush blueberry II. Nutrient uptake and allocation. HortScience 55:1614-1621.

Strik, B.C., A.J. Vance, D.R. Bryla, and D.M. Sullivan. 2019. Organic production systems in northern highbush blueberry: II. Impact of planting method, cultivar, fertilizer, and mulch on leaf and soil nutrient concentrations and relationships with yield from planting through maturity. HortScience 54:1777-1794. ***Outstanding Fruit Publication Award, Amer. Soc. Hort. Sci.***

Ulmer, M.R. and **P.A. Skinkis**. 2020. Cane- and spur-pruned Pinot noir results in similar fruitfulness, yield, and grape ripeness under cool climate conditions. Am. J Enol. Vitic. 4(1):10.

Yang, F-H, D.R. Bryla, S.T. Orr, **B.C. Strik**, and Y. Zhao. 2020. Thermal cooling with over-canopy irrigation systems reduces heat damage and improves fruit quality in northern highbush blueberry. HortScience 55:1365-1371.

Yang, F-H, D.R. Bryla, and **B.C. Strik**. 2019. Critical temperatures and heating times for fruit damage in northern highbush blueberry. HortScience 54:2231-2239.

Yang, F-H, L. DeVetter, **B.C. Strik**, and D.R. Bryla. 2020. Stomatal functioning and its influence on fruit calcium in northern highbush blueberry. HortScience 55:96-102.

Extension publications :

Lukas, S. B., Clark, L., **Davis, A. J.**, Sanchez, D. M., & Brewer, L. J. (2020). Nonlethal bird deterrent strategies in fruit crop production. EM 9286. OSU Extension. https://catalog.extension.oregonstate.edu/em9286

Skinkis, P., J. Pscheidt, A KC, M. Moretti, V. Walton, and C. Kaiser. 2020. Pest management guide for wine grapes in Oregon. Oregon State University Extension Publishing. EM 8413.

Skinkis, P., V. Walton, J. DeFrancesco, B. Edmunds and N. Bell. 2020. "Grape Pests" In Pacific Northwest Insect Pest Management Handbook. Pacific Northwest Extension Publishing.

Strik, B, E. Dixon, A.J. Detweiler, and N. Sanchez. 2020. Growing Blackberries in Your Home Garden: Willamette Valley – Southern Oregon – Central Oregon – Eastern Oregon. EC 1303. September 2020

Strik, B, E. Dixon, A.J. Detweiler, and N. Sanchez. 2020. Growing Raspberries in Your Home Garden: Willamette Valley – Southern Oregon – Central Oregon – Eastern Oregon. EC 1306. August 2020

Strik, B, E. Dixon, A.J. Detweiler, E. Chernoh, and N. Sanchez. 2020. Growing Strawberries in Your Home Garden: Willamette Valley – Southern Oregon – Central Oregon – Eastern Oregon. EC 1307. July 2020

Online Education:

Grower course for blueberry production physiology through OSU PACE (https://workspace.oregonstate.edu/course/online-blueberry-physiology-production-systems-management) by **Strik et al**. (offered twice per year, non-credit).

Strik, B. 2020 - onwards. **Pruning and training modules (individually) for blueberries, kiwifruit, table grapes, blackberries, and raspberries.** 1.25 to 2.5 hours of on-line education, per crop for a home garden and small farmer audience. Through OSU PACE (https://workspace.oregonstate.edu/course/pruning-series) by **Strik** (self-paced, available all year)

OSU Extension Principles of Vineyard Management online class, **Spring 2020** (https://extension.oregonstate.edu/events/principles-vineyard-management) by Skinkis (offered once per year, non-credit)

Websites:

Oregon Wine Research Institute is a research cooperative at Oregon State University and includes the Viticulture and Enology Research and Extension programs. The Institute has a website where program information and industry outreach are available. (http://owri.oregonstate.edu)

Oregon State University Extension Wine Grape Webpages includes technical information for wine grape growers and wineries in Oregon and the Pacific Northwest. Wine grape production (https://extension.oregonstate.edu/crop-production/wine-grapes) and wine production (https://extension.oregonstate.edu/food/wine-beer) content are available.

Spotted Wing Drosophila Website – c.a. 98,546 page views/year for past two years, visitors from 50 countries: https://spottedwing.org/

BMSB: https://agsci.oregonstate.edu/bmsb/brown-marmorated-stink-bug

Honey Bee Lab Website: https://honeybeelab.oregonstate.edu/

Oregon Master Beekeeper Program Website: https://mb.extension.oregonstate.edu/

Berry Crops Web site, NWREC: https://extension.oregonstate.edu/nwrec/berry-crops

Berry Crops Web site, College of Agricultural Sciences: https://agsci.oregonstate.edu/berries-and-small-fruits

Kathy Demchak and Richard P. Marini, Dept. of Plant Science

Research and extension projects.

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Blueberry: *Blueberry cultivar comparison on an "upland" soil.* R. Marini and K. Demchak, Penn State Univ., University Park, PA; J. Luby, Univ. of Minnesota, Minneapolis, MN; Jim Hancock, Michigan State Univ., East Lansing, MI

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Blueberry: *Soil amendments and mulch for blueberry plant establishment.* R. Marini and K. Demchak, Penn State Univ., University Park, PA.

Raspberry and Strawberry: *Optimizing Protected Culture Environments for Berry Crops.* E. Hanson, R. Isaacs, and A. Schilder, Michigan State Univ.; K. Demchak, R. Marini, W.J. Lamont, K. Kelley, D, Decoteau, Penn State University; E. Hoover and M. Rogers, Univ. of Minnesota; M. Pritts and L. Levitan, Cornell Univ.; D. Conner, Univ. of Vermont; B. Sideman, Univ. of New Hampshire; K. Lewers, USDA-Beltsville; M. Glenn (retired), USDA-Kearneysville; N. Paul and C. Halsall, Lancaster Univ., U.K.

Objective 3 - Explore the association between fruit constituents and human health impacts None.

How have the results been disseminated to communities of interest?

The following talks were given on topics related to the above work::

Nov. 15, 2019. Leesport, PA. Strawberry School. 50 in attendance.
Strawberry Production Systems for Mid-Atlantic Growers.

Jan. 29 – 30, 2020. Hershey, PA. Mid-Atlantic Fruit and Vegetable Convention.
Strawberry Production Systems – Basic to Advanced. 140 in attendance.
Tips for Minimizing Wind Damage to High Tunnels. 25 in attendance.

Feb. 1, 2020. New Brunswick, NJ. NOFA-NJ Winter Conference.
Improving Berry Production in Organic Systems. 40 in attendance.

Feb. 7, 2020. Lancaster, PA. Farming for the Future (PASA) Conference.
Getting the Most Profit from Your High Tunnel (co-presented with A. King). 80 attended.
Feb. 14, 2020. Fleetwood, PA. Berks-Schuylkill Winter Vegetable Meeting. 50 in attendance.
Keys to Successfully Establishing a Blueberry Planting.

A series of 5 videos was was completed that utilized knowledge gained as part of the project on high tunnel production. The entire series is called: "High Tunnel Structures: The Basics".
https://extension.psu.edu/high-tunnel-structures-the-basics

Provided, organized and conducted a day and half workshop of extension educators and other PSU personnel on high tunnel and soilless systems production with F. Di Gioia and E. Sánchez.

What we plan to do during the next reporting period to accomplish the goals.

The blueberry variety and mulch/amendment study will be continued.

A trial to optimize media type for containerized production will be undertaken, as using the correct media type, along with having a long growing season, is a major key to obtaining high yields.

Outreach efforts will continue.

Research results

In the day-neutral variety x high tunnel strawberry trial, 'Albion', 'Cabrillo', 'San Andreas' and 'Sweet Ann' were grown in containers in high tunnels with or without plastic covers. The experiment was a randomized complete block design with 3 blocks. Plants were irrigated with a complete fertilizer at 100 ppm N, which the nursery suggested might encourage 'Cabrillo' and 'Sweet Ann' remain vegetative. This wasn't the case with 'Cabrillo', but 'Sweet Ann' and 'San Andreas' took longer to bloom than 'Albion' or 'Cabrillo' did. High nitrogen could have been a factor in quality with 'Cabrillo' however, which produced the highest total yields, but its fruit was soft and somewhat bitter when temperatures were hot. 'Cabrillo' was the most susceptible variety to fruit anthracnose when grown without a cover (10.2% of fruit affected). Fruit anthracnose incidence was reduced greatly (by four-fifths with 'San Andreas') or eliminated ('Sweet Ann') in tunnels compared to outside when no fungicides were used. Increasingly, PA growers are indicating interest in tunnels or greenhouses to give them greater control over certain diseases. This could be especially for valuable for organic producers.

Might disease control be the factor that finally drives U.S. strawberry producers to adopt protected culture?

Our blueberry mulch/amendment study is a multi-year study designed mainly to look at differences between incorporating hardwood (oak of unknown species) or softwood (white pine) sawdust into the planting whole compared to incorporating peat moss as a control. A second question we wanted to answer was whether it made a difference if hardwood or softwood sawdust was used as a mulch when peat moss was incorporated into the planting hole. This has been a recurring question from growers. Yields were highest when peat moss was incorporated into the planting hole compared to hardwood sawdust, and numerically higher when peat moss was used compared to softwood sawdust. If peat moss is incorporated into the planting hole, yields are very similar regardless of which type of sawdust is used as a mulch. If sawdust must be used instead of peat moss as both a mulch and a planting hole amendment, softwood sawdust tended to result in higher yields than hardwood. There were no significant difference in leaf nitrogen levels among treatments.

'Northland' has been the most productive variety out of the ten varieties in our trial, which also includes 'Bonus', 'Chandler', 'Draper', 'Huron', 'Legacy', Liberty', 'Nelson', 'Reka', and 'Superior'. 'Northland', 'Nelson', and 'Reka' has been the favorites for flavor (subjectively rated) though 'Patriot' in our neighboring mulch study also scores high marks. Unfortunately, 'Northland' is tied with 'Superior' and 'Reka' for smallest berry size. This means that it may be better suited as a variety for home gardens or commercial operations if it can be mechanically harvested, but it probably isn't ideal for you-pick or farm market sales.

4. List retrievable or archived publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications. Please use ASHS style.

Cramer, M.E., K. Demchak, R. Marini, and T. Leskey. 2019. UV-Blocking High Tunnel Plastics Reduce Japanese Beetle (*Popillia japonica*) in Red Raspberry. HortScience 54:903-909.

United States Department of Agriculture

NCCC-212 State Report 2020 – USDA, Beltsville, MD, Lewers
CONFIDENTIAL PLEASE

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Strawberry:

Title: *Strawberry cultivar development.* Kim Lewers, USDA, Beltsville, MD;

Dissemination:

Lewers, K.S., P. Castro, J.F. Hancock, C.K. Weebadde, J.V. Die, and J.L. Rowland, 2019. Evidence of epistatic suppression of repeat fruiting in cultivated strawberry. BMC plant biology, 19(1), p.386-403. https://doi.org/10.1186/s12870-019-1984-7

Lewers, K.S., M.J. Newell, E. Park, and Y. Luo. 2020. Consumer preference and physiochemical analyses of fresh strawberries from ten cultivars. Int. J. Fruit Sci. https://doi.org/10.1080/15538362.2020.1768617

Lewers, K.S., J.M. Enns, and P. Castro. 2019. 'Keepsake' strawberry. HortScience 54(2):362-367.

Lewers, K.S. 01/22/2018 New Varieties - Review of Releases from Various Programs. Standouts from each. 2018 North American Strawberry Growers Association Meeting, New Orleans, LA. (Presented by Kevin Schooley due to Federal government shut-down)

Lewers, K.S. 02/27/2018 What makes low tunnels work? Mid-Atlantic Strawberry Association. Virginia Beach, VA.

Lewers, K.S. 05/22/2019 Update from the USDA-strawberry breeding program at Beltsville. 2019 UMD Wye Research Center Strawberry Twilight Meeting. Queenstown, MD.

Lewers, K.S. 02/22/2019 UMD and USDA focus on strawberry flavor. 2019 Bay Area Fruit Meeting. Queenstown, MD.

Lewers, K.S. 02/04/2019 Developing strawberry cultivars with improved fruit quality. 2019 North American Strawberry Symposium. Orlando, FL.

Lewers, K.S. 01/31/2019 Putting flavor and disease resistance first in a strawberry breeding program. 2019 Mid-Atlantic Fruit and Vegetable Convention. Hershey, PA.

Lewers, K.S. 11/27/2018 Wye and USDA updates. 2018 Grower Client Meeting, Bob Rouse Agriculturalist, LLC. Denton, MD.

Lewers, K.S. 12/02/2019. Beltsville update. 2019 Grower Client Meeting, Bob Rouse Agriculturalist, LLC. Denton, MD.

Lewers, K.S. 11/19/2019 Strawberry Cultivars and Production Options at the UMD Mid-Atlantic Crop Management School. Ocean City, MD.

Lewers, K.S. 01/20/2020 Introducing the New Strawberry Keepsake. 2020 North American Strawberry Growers Association Meeting. San Antonio, TX.

Lewers, K.S. 01/13/2020 Strawberry variety testing and quality evaluation and the strawberry breeding program at USDA, Beltsville. Delaware Ag Week – Fruit Session. Harrington, DE.

Lewers, K.S. 03/03/2020 New USDA strawberry cultivar and low-tunnel tips. Mid-

Atlantic Strawberry Association. Virginia Beach, VA.
Lewers, K.S. 02/13/2020 New cultivars and low-tunnel films × cultivar interactions. UMd Western Maryland Research and Education Center, Keedysville, MD.
Future plans: Release B2360 as 'Cordial', a late-season spring-fruiting strawberry.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Strawberry:
Title: *Strawberry production in low tunnels.* Kim Lewers, Dave Fliesher, Craig Daughtry, Brian Vinyard, USDA, Beltsville, MD
Dissemination:
Lewers, K.S., D.H. Fleisher, C.S.T. Daughtry, and B.T. Vinyard. 2020. Low-tunnel strawberry production: Comparison of cultivars and films. Int. J. Fruit Sci. https://doi.org/10.1080/15538362.2020.1768616
Lewers, K.S. 01/11/2018 Growing Great Strawberries in the Mid-Atlantic. 2018 CASA Future Harvest Conference, Hyattsville, MD.
Lewers, K.S. 11/28/2017 What makes low tunnels work? 2017 Grower Client Meeting, Bob Rouse Agriculturalist, LLC. Denton, MD.
Lewers, K.S. 02/02/2017 Low tunnels for strawberry production. 2017 Mid-Atlantic Fruit and Vegetable Convention. Hershey, PA.
Lewers, K.S. 11/27/2018 Wye and USDA updates. 2018 Grower Client Meeting, Bob Rouse Agriculturalist, LLC. Denton, MD.
Lewers, K.S. 11/07/2019 Cover crops in strawberry production at the 2019 Northeast Cover Crop Council Conference. College Park, MD.
Lewers, K.S. 11/02/2019 Strawberry cultivars and production practices for the Mid-Atlantic. 16th Annual Small Farm Conference, UMD Eastern Shore Extension Demonstration Farm, Princess Anne, MD.
Lewers, K.S. 12/02/2019. Beltsville update. 2019 Grower Client Meeting, Bob Rouse Agriculturalist, LLC. Denton, MD.
Lewers, K.S. 11/19/2019 Strawberry Cultivars and Production Options at the UMD Mid-Atlantic Crop Management School. Ocean City, MD.
Lewers, K.S. 01/21/2020 Winning combinations of dayneutral cultivars and low-tunnel films. 2020 North American Strawberry Growers Association Meeting. San Antonio, TX.
Lewers, K.S. 03/03/2020 New USDA strawberry cultivar and low-tunnel tips. Mid-Atlantic Strawberry Association. Virginia Beach, VA.
Lewers, K.S. 02/13/2020 New cultivars and low-tunnel films × cultivar interactions. UMd Western Maryland Research and Education Center, Keedysville, MD.
Future plans: Use low-tunnels for Objective 1 to breed repeat-fruiting strawberry cultivars.

Objective 3 - Explore the association between fruit constituents and human health impacts

Strawberry:

Title: *Effects of low-tunnel production system on strawberry fruit constituents.* Tianbao Yang, Kim Lewers, Craig Daughtry, USDA-Beltsville

Dissemination:

Dong, W., Y. Lu, T. Yang, F. Trouth, K.S. Lewers, C.S. Daughtry, and Z.M. Cheng, 2019. Effect of Genotype and Plastic Film Type on Strawberry Fruit Quality and Post-Harvest Shelf Life. Int. J. Fruit Sci. https://doi.org/10.1080/15538362.2019.1673873

Future plans: None

3. News and summaries.

Cultivars:

'Flavorfest' is a mid-season, spring-bearing cultivar that has been out awhile and liked for **reliably high yield and good flavor**. It is resistant to anthracnose fruit rot in the *Colletotrichum accutatum* complex growing naturally in our fields. Some growers and nurseries report that 'Flavorfest' flavor is better on clay soils than sandy soils. North Carolina reports it no longer yields well there (reason unknown). Some plug plants have been infected with *Phytophthora* when sold to growers and have died in plasticulture. This has not been widely reported with bare-root dormant plantings in matted-row systems. Supply is good for bare-root dormant plants, but struggling with plug plants.

'Keepsake' is a newer mid-season, spring-bearing cultivar, also resistant to *C. accutatum* complex in our fields. This is the first cultivar resulting from our increased emphasis on postharvest quality, so this cultivar should be recommended to growers who need their strawberries to have **longer shelf life**. It also **excels in sweetness** and flavor, even better than 'Flavorfest' and 'Earliglow'. Its yield is very good, but slightly lower than 'Flavorfest'. Only a few nurseries are licensed.

'Cordial' is a **late-season** cultivar in the process of release. It also is resistant to *Colletotrichum accutatum* complex growing naturally in our fields. It has very high yields of **very large fruit**…redefines "large" for our program. Postharvest storage quality is as good as 'Keepsake'. The fruit are subacid, pH is higher than that of 'Flavorfest' and 'Earliglow', so without sunshine, the flavor is still friendly or "cordial". With sunshine, the flavor is sweet but not tart. A few nurseries have test plants under MTAs.

Genetics: Repeat fruiting controlled by one mapped gene and at least two suppressors

Strawberry repeat fruiting was mapped by several groups to a single locus. I mapped it to the same locus in two populations segregating for other traits, and also confirmed repeat fruiting is conferred by the dominant allele at that locus. But when I tried to apply the markers to the breeding program, they weren't helpful. I used all the markers

from the entire linkage group the repeat-fruiting locus mapped to so there would be no chance of disassociation due to recombination. And I tested those markers on all the parents of all the families I used one year to try to breed for a repeat-fruiting strawberry cultivar.

Problem 1: If the markers said the parent should be once fruiting, it was. BUT if the markers said the parent should be repeat fruiting, there was only a 50-50 chance that it would be. It is true that once-fruiting genotypes can, in cool weather, sometimes fruit out of season like repeat-fruiting genotypes. This has made us feel that it would be impossible to discern between genetic and environmental effects. However, it wasn't the parents that had all the markers for once-fruiting that showed inconsistent phenotypes. It was the parents that showed markers for repeat fruiting that had phenotypes that didn't agree with the markers. The fact that half the parents with repeat-fruiting markers behaved as once-fruiting, pointed to a second gene suppressing the one we all mapped.

Problem 2: The only segregation ratios I should have seen in the resulting families from a cross of two repeat-fruiting parents were all repeat-fruiting or 3 repeat-fruiting : 1 once-fruiting. But there were many other segregation ratios from large families. I knew repeat fruiting genotypes could be homozygous or heterozygous at the mapped locus, and once-fruiting would be homozygous recessive at that locus. I considered that the suppressor gene could either be dominant or recessive and would be unlinked to the one we all mapped. I considered every possible parental combination and calculated all possible resulting segregation, and compared them with what I observed. The table below is handy as a quick key to understanding the genetics behind the segregation rations for this and other traits that don't behave simply. Red text indicates the "informative ratios" that are not seen with a single locus and differentiate between a dominant vs recessive suppressor. It's the suppressor genes that are sensitive to temperature; one to heat, the other to winter cold.

Table 3 Possible segregation ratios of progeny resulting from crosses of repeat-fruiting (RB) and once-fruiting (jb) commercial strawberry parents. Possible progeny ratios are listed on the left. Parental combinations that would result in each segregation ratio are provided for the known mapped dominant gene conferring repeat fruiting with no suppressor, with a hypothetical dominant suppressor, or with a recessive suppressor of the known dominant gene.

Progeny ratios	No suppressor			Dominant suppressor			Recessive suppressor		
All RB	RBxRB	RB and jb		RBxRB	RB and jb		RBxRB	RB and jb	jbxjb
1jb:3RB				RBxRB			RBxRB	RB and jb	
3jb:5RB							**RBxRB**	**RB and jb**	
7jb:9RB							**RBxRB**	**RB and jb**	
1jb:1RB		RB and jb			RB and jb	jbxjb		RB and jb	jbxjb
5jb:3RB					RB and jb			RB and jb	
3jb:1RB	RBxRB				RB and jb	jbxjb		RB and jb	jbxjb
13jb:3RB						**jbxjb**			
7jb:1RB						**jbxjb**			
All jb			jbxjb	RBxRB	RB and jb	jbxjb			jbxjb

New disease in our fields, *Colletotrichum siamense*:

A species from the dreaded *Colletotrichum gloeosporioides* complex has arrived (confirmed by Mengjun Hu, UMD). It's in our seedling field, so that means it's "native". This is terrible for growers, chaining them to fungicides until resistant cultivars can be developed. But the good news is that not all our families had dead plants, and some families showed live plants among a few dead ones. There were parents in common between families with a lot of dead plants. Therefore, I have high hopes this means our program has some genetic resistance, and we can release resistant cultivars now that the pathogen is in our fields.

4. Publication summary

Lewers, K.S., D.H. Fleisher, C.S.T. Daughtry, and B.T. Vinyard. 2020. Low-tunnel strawberry production: Comparison of cultivars and films. Int. J. Fruit Sci. https://doi.org/10.1080/15538362.2020.1768616

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Lewers, K.S., J.M. Enns, and P. Castro. 2019. 'Keepsake' strawberry. HortScience 54(2):362-367.

Dong, W., Y. Lu, T. Yang, F. Trouth, K.S. Lewers, C.S. Daughtry, and Z.M. Cheng, 2019. Effect of Genotype and Plastic Film Type on Strawberry Fruit Quality and Post-Harvest Shelf Life. Int. J. Fruit Sci. https://doi.org/10.1080/15538362.2019.1673873

NCCC-212 Annual Report for 2020: Small Fruit
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List of projects

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs.

Blackberry and Raspberry:

1. *Using synteny and candidate genes to identify loci controlling fruit sweetness in blackberry.* Jason Zurn, Mandie Driskill, Nahla Bassil, USDA ARS NCGR-Corvallis, OR; Margaret Worthington, John Clark, University of Arkansas, Fayetteville, AR; Chad Finn, USDA ARS HCRU-Corvallis, OR; Dorrie Main, Sook Jung, Washington State University, Pullman, WA; Lailiang Cheng, Cornell University, Ithaca, NY.
2. *Developing two fingerprinting sets in red raspberry.* Jason Zurn, Mandie Driskill, Kim Hummer, Nahla Bassil, USDA ARS NCGR-Corvallis; Chad Finn, Jana Lee, USDA ARS HCRU-Corvallis, OR; Michael Dossett, BC Berry Cultivar Development Inc. (in partnership with Agriculture and Agri-Food Canada), Agassiz, Canada.
3. *Fine mapping black raspberry aphid resistance to the North American large raspberry aphid.* Christina Mulch, Kelly Vining, Oregon State University, Corvallis, OR; Nahla Bassil, Jill Bushakra, USDA ARS NCGR-Corvallis, OR; Chad Finn, Jana Lee, USDA ARS HCRU-Corvallis, OR; Michael Dossett, BC Berry Cultivar Development Inc. (in partnership with Agriculture and Agri-Food Canada), Agassiz, Canada.
4. *Blackberry fingerprinting set to confirm parentage in new cultivars and identity in the NCPN collection.* Nahla Bassil, USDA ARS NCGR-Corvallis, OR., April Nyberg,

USDA ARS NCGR-Corvallis, OR; Chad Finn, Bob Martin, Amanda Lake, USDA ARS HCRU-Corvallis, OR.

5. *GWAS study by phenotyping diverse Rubus species and cultivars.* Jill Bushakra, Nahla Bassil, and Kim Hummer, USDA ARS NCGR-Corvallis OR; Pairwise Plants, Durham, NC, Plant Sciences, Inc., Watsonville, CA; Courtney Weber, Cornell University, Ithaca, NY; Gina Fernandez, North Carolina State University, Raleigh, NC; Margaret Worthington, University of Arkansas, Fayetteville, AR; Michael Dossett, BC Berry Cultivar Development Inc. (in partnership with Agriculture and Agri-Food Canada), Agassiz, Canada.

Blueberry:

1. *Confirming identity of blueberry cultivars by DNA Fingerprinting.* Nahla Bassil, Kim Hummer, April Nyberg, USDA ARS NCGR-Corvallis, OR; Ozgecan Yalcin, Oregon State University, Department of Horticulture, Corvallis, OR
2. *Determining ploidy using leaves and pollen grains of diverse Vaccinium species.* Sunny Green, Kim Hummer USDA ARS NCGR-Corvallis, OR; Ryan Contreras, Oregon State University, Department of Horticulture, Corvallis, OR
3. *Evaluating Vaccinium germplasm for heat tolerance, drought tolerance, and cold tolerance.* Todd Anderson, Nahla Bassil, Kim Hummer USDA ARS NCGR-Corvallis, OR; Scott Orr, Dave Bryla, USDA ARS HCRU, Corvallis, OR
4. *Developed a genetic framework to improve the efficiency of bioactive delivery from blueberry.* Nahla Bassil, Kim Hummer, USDA ARS NCGR-Corvallis, OR; Molla F. Mengist, Haley Burtch, Hawi Debelo, Marti Pottorff, Hamed Bostan, Candace Nunn, Sydney Corbin, Colin D. Kay, Mary Ann Lila, Mario G. Ferruzzi, Massimo Iorizzo, Plants for Human Health Institute, North Carolina State University, Kannapolis, NC
5. *Phenotyping blueberry for fruit quality traits.* Nahla Bassil, Kim Hummer, USDA ARS NCGR-Corvallis, OR; Marti Pottorff, Massimo Iorizzo, Penelope Perkins-Veazie, Mary Ann Lila, Plants for Human Health Institute, North Carolina State University, Kannapolis, NC; Ted Mackey, USDA-ARS-HCRU, Corvallis, OR
6. *Developing a high throughput genotyping platform for blueberry and cranberry.* Nahla Bassil, Mandie Driskill, USDA ARS NCGR-Corvallis, OR; Massimo Iorizzo, Plants for Human Health Institute, North Carolina State University, Kannapolis, NC; Patrick Edger, Michigan State University, Department of Horticulture, E. Lansing, MI; Patricio Munoz, University of Florida, Horticultural Science Department, Gainesville, FL; David Chagne, Plant & Food Research Limited, Palmerston North, New Zealand
7. *Assisting Breeding Insight (BI) in enabling genomic selection in blueberry.* Nahla Bassil, USDA ARS NCGR-Corvallis, OR; Dongyan Zhao, Moira Sheehan, Cornell University, Department of Plant Biology; Amanda Hulse-Kemp, USDA-ARS; Jodi Humann, Dorrie Main, Washington State University, Department of Horticulture, Pullman, WA
8. *Testing Allegro Targeted Genotyping for blueberry genome wide association.* Nahla Bassil, USDA ARS NCGR-Corvallis, OR; Amanda Hulse-Kemp, USDA-ARS-GBRU; Lauren Redpath, Rishi Aryal, and Hamid Ashrafi, North Carolina State University, Horticultural Science Department, Raleigh, NC

Strawberry:

1. *Assessing genetic diversity in the cultivated strawberry (Fragaria ×ananassa) collection at the National Clonal Germplasm Repository.* Jason Zurn, Nahla Bassil, Kim Hummer, USDA ARS NCGR-Corvallis, OR; Steve Knapp, Michael Hardigan, UC Davis, CA.
2. *Evaluating genotype x environment interactions for predicting SSC in strawberry*. Jason Zurn, Nahla Bassil, USDA ARS NCGR-Corvallis, OR; Mulusew Ali, Craig Hardner University of Queensland, St. Lucia, QLD, Australia; Vance Whitaker, University of Florida, Wimauma, FL; Chad Finn, USDA ARS HCRU-Corvallis, OR; Jim Hancock, Michigan State University, E. Lansing, MI; Iraida Amaya, IFAPA, Malaga, Spain; Helen Cockerton, Richard Harrison, NIAB-EMR, East Malling, United Kingdom; Lise Mahoney, Tom Davis, University of New Hampshire, Durham, NH; Jodi Neal, Queensland Department of Agriculture and Fisheries, Nambour, Australia.
3. *Phenotyping diverse strawberry cultivars in Corvallis, Oregon.* Kim Hummer, Nahla Bassil, and Jason Zurn, USDA ARS NCGR-Corvallis, OR

Other small fruit crops:

1. *Developing a Ribes fingerprinting set for germplasm management.* Nahla Bassil, Jill Bushakra, Kim Hummer, USDA-ARS NCGR-Corvallis, OR

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Objective 3 - Explore the association between fruit constituents and human health impacts.

Impact statements

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs.

Blackberry and Raspberry:

Using synteny and candidate genes to identify loci controlling fruit sweetness in blackberry: Increased sugar content is one of the most important traits desired by blackberry consumers. A synteny-based approach was used to identify candidate genes responsible for sugar production in blackberry (*Rubus* L.). Three sugar quantitative trait loci (QTL) were identified from the GDR QTL database that are conserved among apple, peach, and alpine diploid strawberry. The physical regions for these QTLs were identified in the *F. vesca* v1.1 assembly and 26 genes with functions associated with sugar production were extracted. Additionally, 789 sugar-associated genes were extracted from the *M. domestica* v3.0.a1 assembly. The strawberry and appl*e* genes were used to conduct a BLAST search in the GDR *Rubus* reference transcriptome. Of 279 *Rubus* candidate transcripts identified, predicted exons were used to design 9,355 Hyb-Seq baits. The baits covered 99.6% of the targeted regions. These baits were used in conjunction with PacBio

sequencing to genotype 40 cultivars with high and low sugar content from the University of Arkansas and USDA blackberry breeding programs. A total of 430,167 high quality circular consensus sequences (CCS) were generated. Alignment to the 'Hillquist' blackberry and *Rubus occidentalis* genomes, followed by variant identification, resulted in 929,430 and 1,324,854 markers, respectively. Welch's t-test and a Benjamini-Hochberg correction identified 467 and 312 significant loci from the 'Hillquist' and the *R. occidentalis* genotype tables, respectively. Population structure modeling identified a total of 173 loci that were significantly ($\alpha = 0.05$) associated with sugar production regardless of population structure. A set of 111 KASP markers were developed and validated on 192 blackberries from the USDA-ARS HCRU and University of Arkansas breeding programs and 48 markers distributed across 16 genomic regions were found to be significantly associated with soluble solids content. A region on chromosome 1, known as qSSC-Ruh-ch1.1, was stable across three growing environments and was responsible for a 1.5 °Brix increase in soluble solids. The regions identified represent the first sweetness related QTLs in blackberry and the new markers will be used to develop sweeter cultivars.

Developing two fingerprinting sets in red raspberry:
DNA sequence data from the public domain and that we have previously generated was mined for structural variants and long core repeat simple sequence repeats after alignment to the black raspberry genome. At this time, we are identifying single copy polymorphic loci to compile a list of genome-wide single copy SSRs and structural variants. Once identified we plan to develop 1,000 RhAMPSeq markers to use in genotyping our red raspberry collection. A subset of the polymorphic SSRs will also be developed into a fingerprinting set and used to genotype these same individuals.

Fine mapping black raspberry aphid resistance to the North American large raspberry aphid:
Market expansion of black raspberry is currently hindered by aphid-vectored viruses, such as Black Raspberry Necrosis virus. Natural, genetic resistance to aphids exists and has been identified from three geographic sources: Maine, Michigan, and Ontario, Canada. These sources are being used by Chad Finn to breed cultivars with durable aphid resistance. We have developed three new populations (ORUS 5291, ORUS 5296, and ORUS 5306), that are expected to segregate for each of these three sources, to fine map this trait. Segregation of resistance in each of these populations was phenotypically evaluated by aphid inoculation resulting in segregation ratios of 1:1 resistant (R) to susceptible (S) by Chi-squared analysis. Differential expression in 10 R and 10 S seedlings is being assessed with IsoSeq (Full-Length Isoform Sequencing) for one source (ORUS 5306). In addition, Illumina Sequencing for 5 R and 5 S seedlings from each population before and after aphid inoculation is being evaluated. We plan on performing fine mapping of QTL (quantitative trait loci) for aphid resistance in each of these populations using previously developed microsatellite markers and new markers identified using IsoSeq. Our goals are to use these resources to develop useful genetic markers for each source of resistance, and to allow pyramiding of these resistance loci in new breeding populations.

Blackberry fingerprinting set to confirm parentage in new cultivars and identity in the NCPN collection:
An 8-SSR fingerprinting set has already been developed to fingerprint and validate parentage in blackberries. We used this fingerprinting set to confirm parentage of three new releases from Chad Finn's breeding program, 'Eclipse', 'Galaxy', and 'Twilight'. Genotyping and parentage

analyses are under way for 38 of the selections and parents from the USDA-ARS-HCRL Blackberry Breeding Program. Parentage analysis is in progress to identify the genotype that could have resulted from the reported cross.

GWAS study by phenotyping diverse Rubus *species and cultivars.*
Provided 647 accessions from the USDA-ARS-NCGR *Rubus* collection for genotyping and phenotyping. The accessions were propagated by Pairwise Plants to generate at least 10 plants of each genotype and are being grown in pots under protection in Watsonville, CA. The accessions will be evaluated for 79 traits in Watsonville, CA. Traits include plant architecture, cane characteristics, flower characteristics, fruit characteristics, fruit quality, and seed characteristics. A selection of six standard genotypes are being grown and evaluated at USDA-ARS, Corvallis, OR, Cornell, Ithaca, NY, NCSU, Raleigh, NC, and Agassiz, Canada for 10 traits.

Blueberry:

Confirming identity of blueberry cultivars by DNA Fingerprinting:
The genotypic identity of the blueberry cultivars in the NCGR collections is critical to genebank management and operations. We had previously developed a 5-SSR and a 10-SSR fingerprinting set. Genotyping 367 samples with one or both of these SSR sets and parentage analysis, where possible, detected 96 plants representing 54 cultivars that were true-to-type (TTT) cultivars, 13 sets of homonyms and ten groups of synonyms. Parentage analysis identified five of the TTT cultivars among the homonyms ('Bluecrop', FL 4B, 'Nelson' and 'Clara') and 'Elizabeth' among the synonym sets. Identity challenges were detected in 50 plants representing 23 cultivars. We have obtained leaf samples of parents and cultivars that had genotypes that were inconsistent with the reported parentage from up to seven different sources and are in the process of genotyping them to resolve these identity challenges. Confirmed blueberry genotypes will benefit the germplasm community for use in continued breeding and genetic studies.

Developed a genetic framework to improve the efficiency of bioactive delivery from blueberry:
In collaboration with Massimo Iorizzo and his team at NCSU, we applied a novel high-throughput *in vitro* gastrointestinal digestion model to phenotype bioaccessibility of phenolic acids in 66 diverse blueberry accessions from the NCGR collection in 2017-2019. Results revealed significant ($P<0.05$) differences between accessions, years, and accession by year interaction for relative and absolute bioaccessibility of flavonoids and phenolic acids. Broad sense heritability estimates revealed low to moderate inheritances of relative and absolute bioaccessibility, suggesting that besides environmental variables, genetics factors could control bioaccessibility of phenolics. Acylated anthocyanins had significantly higher relative bioaccessibility than non-acylated anthocyanins. Correlation analysis indicated that relative bioaccessibility did not show significant association with fruit quality or raw concentration of metabolites. The study also identified accessions that have high relative and absolute bioaccessibility values. Overall, combining the bioaccessibility of phenolics with genetic and genomic approaches will enable the identification of genotypes and genetic factors influencing these traits in blueberry. Data from this study will be uploaded to GRIN-Global.

Phenotyping blueberry for fruit quality traits:
In the spring and summer of 2020, we harvested ripe blueberry fruit from 196 seedlings for the 'Draper' x 'Jewel' population, 200 accessions from the NCGR Field collection, and 960 northern

highbush blueberry accessions (GenStudy) from the 2016 and 2017 USDA-ARS-HCRL breeding program as part of the VacCAP project. We use the Texture Analyzer to simultaneously evaluate blueberry texture (Tx), stem scar diameter (ScD), scar tear (ScT), fruit weight (Wg) and shelf life indicators such as wrinkle/shrivel (Wr/Shr), mold, leakage (Lk) at harvest time and six weeks post-harvest (stored at 4 °C). Preliminary analyses indicated a wide range of variation for most of the traits and parameters. Fruits for non-volatile chemistry analysis were frozen and shipped to Co-PIs Perkins-Veazie and Lila.

Developing a high throughput genotyping platform for blueberry and cranberry:
We lead the Genotyping Team for the VacCAP with the objective to develop a high-throughput genotyping platform for blueberry and cranberry. We surveyed 18 core and non-core *Vaccinium* groups to identify their needs for a high-throughput platform that can be of use to the *Vaccinium* research community. We began compiling a SNP catalog by obtaining 47,025 SNPs of interest from linkage maps and QTL studies. We obtained sequence data from collaborators and NCBI and cleaned them up and stored them to use for SNP detection once the pangenome is ready. We also identified four high-throughput data providers that could meet our needs, organized webinars from these companies to provide an overview of their services to the *Vaccinium* community, and are in the process of evaluating their offers.

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Assisting Breeding Insight (BI) in enabling genomic selection in blueberry:
We identified 384 diverse blueberry accessions and collected them from the NCGR and the blueberry community to test the genotyping platform selected (DArTag), once it is ready. We provided leaf tissue for ~600 samples for two companies to test their blueberry DNA extraction protocols. We worked with Ted Mackey and Michael Hardigan on identifying traits to phenotype ~2,700 seedlings from the 2017 USDA-ARS-HCRL seedling field. In collaboration with Amanda Hulse-Kemp (USDA-ARS) and Jodi Humann (GDR, WSU), we compiled a comprehensive list of all traits being used to phenotype blueberry, and phenotyping method from the blueberry research and breeding community (ARS, university, and private companies) and converted the information into the BI template that is interoperable with BreedBase.

Testing Allegro Targeted Genotyping for blueberry genome wide association:
In collaboration with Hamid Ashrafi and his team at NCSU, 1.7 million SNPs were selected, and the flanking sequences were extracted. Single primer enrichment technology (SPET) was used to specifically target SNPs of interest in a diversity panel of 252 individuals that included 77 accessions from the NCGR. Phenotypic data for phenological traits were collected in 2019 and 2020 from the 77 accessions at the NCGR and ripe fruit were shipped to NCSU for fruit quality trait and anthocyanin analyses. The pooled paired-end libraries of 184 and 96 individuals of two diversity panels were used to generate 308 GB of data with an average of 900 MB per genotype. Two bioinformatics pipelines were used for SNP identification. Data analysis is in process. Through association of these SNPs to measured phenotypic traits of the diversity panels, candidate genes for fruit size, weight, and color, as well as soluble solid content, titratable acidity, pH, and different anthocyanins, will be investigated. Further, comparative analysis of resequencing data of native diploid, tetraploid, and hexaploid *Vaccinium* species will be used to ascertain the origin of introgressed SNPs.

Strawberry:

Assessing genetic diversity in the cultivated strawberry (Fragaria ×ananassa) collection at the NCGR:
The USDA-ARS national collection includes 560 diverse *Fragaria ×ananassa* accessions of modern and historical U.S. and foreign cultivars and breeding selections. An initial core subset of 447 *Fragaria* cultivars (304) and world species (143) was identified in the 1980s by the curator and the Small Fruit Crop Germplasm committee members to represent maximum genetic diversity. Very little has been done to characterize these accessions genotypically. Pedigrees are unknown for many. Since the original core designation, an additional 160 cultivated strawberry cultivars were received by NCGR. The objectives of this study is to genotype the entire *F. ×ananassa* collection, assess genetic structure and diversity, confirm pedigrees within the collection, and identify a core collection based on genetic data. The Knapp group has already genotyped 211 of these accessions with the IStraw35 Axiom strawberry array. We submitted DNA from the remaining 332 accessions for genotyping with a new strawberry array that contains 6,000 markers in common with the IStraw35 Axiom array. Population structure analysis of the *F. ×ananassa* collections revealed eight sub-populations associated with geographical regions or major breeding programs. F_{st} values were very low confirming the narrow genetic diversity within cultivated strawberry germplasm and may also be related to the germplasm sharing by 1950's era breeding programs. Two 100 individual core collections were developed that maximize diversity within the collection and have a uniform distribution of alleles. These core collections will help breeding programs streamline characterization of the collection for useful traits. Pedigree confirmation is underway.

Evaluating genotype x environment interactions for predicting SSC in strawberry:
Strawberry fruit flavor is due to a complex mix of sugars, acids, and aromatic compounds. Consumers tend to prefer sweeter strawberry cultivars. Therefore, sweetness has been an important target trait for breeders. The majority of strawberry soluble solids are sugars, and soluble solid content (SSC) is used as a proxy to determine sweetness. A strong genotype × environment (G × E) interaction has been observed for SSC, causing difficulties when studying the genetics underlying SSC in individual environments. A meta-analysis of multiple environments may provide new insights toward unraveling the genetics underlying SSC. Genotypic and phenotypic data were collected for 3,407 total individuals from seven breeding programs (four in the United States, and one each from Spain, the United Kingdom, and Australia). Subsets of the individuals were evaluated for SSC in 19 environments. Genotypic information from the 90K and 35K Axiom arrays was reduced to 12,951 high quality single nucleotide polymorphism markers shared by all accessions. Missing data was imputed, linkage disequilibrium was calculated, and a relationship matrix was constructed for all samples. Using this information, multiple G × E models were evaluated for their predictive ability among environments. Results are being analyzed to identify genomic models that can be used to predict strawberry SSC in new environments.

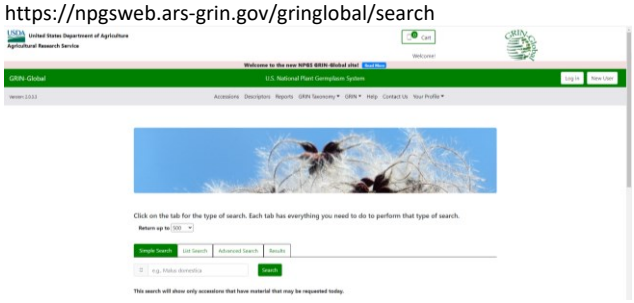
Other Small Fruit Crops

Developing a Ribes fingerprinting set for germplasm management:
We identified 13 high core repeat SSRs from the literature that appeared to be polymorphic in different species. We evaluated them in a testing panel of 12 accessions representing *R. aureum, R. nigrum, R. uva-crispa*, *R. spicatum*, *R. petraeum*, and *R.* × *nidigrolaria*. We identified 7 SSRs that appear polymorphic across these species and optimized this 7-SSR *Ribes* fingerprinting set and will be testing it for ability to identify 51 accessions in the NCGR collection.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.
Objective 3 - Explore the association between fruit constituents and human health impacts.
Data, germplasm/cultivar descriptions, research results, for discussion at the meeting. Note that this data is preliminary and not for public dissemination

Genus	Accessions	Field locations	SH /GH locations	Total plant locations	Total seed accessions
Fragaria (Strawberry)	2,013	900	1,726	2626	652
Ribes (Currant, Gooseberry)	1,299	651	65	716	672
Rubus (Blackberry, Raspberry)	2,221	-	948	948	1819
Sambucus (Elderberry)	201	47	1	48	170
Vaccinium (Blueberry, Cranberry)	1,852	311	686	1,001	1072

Berry collections summary for the National Clonal Germplasm Repository.
GRIN-Global searches for particular accessions can be obtained by searching:
https://npgsweb.ars-grin.gov/gringlobal/search



4. Publications

Bassil, N.V., Bidani, A., Nyberg, A.M., Hummer, K.E., Rowland, L.J. 2020. Microsatellite markers confirm identity of blueberry plants in the USDA-ARS National Clonal Germplasm Repository collection. Genetic Resources and Crop Evolution. 67:393-409. https://doi.org/10.1007/s10722-019-00873-8.

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Zurn, J.D., Ivors, K.L., Cole, G.S., Knapp, S.J., Hummer, K.E., Hancock, J.F., Finn, C.E., Bassil, N.V. 2020. Assessing cultivated strawberries and the *Fragaria* Supercore for resistance to soilborne pathogens. Journal of American Pomological Society. 74(1):18-23.

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REPORT TO NCCC212, 2020
Utah State University

Brent Black (brent.black@usu.edu)

Objective 2. Develop production practices tailored to climatic and market needs:

Sub-objective: Develop improved management strategies for high tunnel berry production in a high-elevation arid climate.

- Raspberry.

Work continues to fine tune management practices for primocane raspberries in protected cultivation (HT and LT). Utah growers are interested in this system to advance primocane production for reliable fall yields before fall frost). We have plots at the campus research farm and at 4 commercial farms ranging from Bear Lake in the north to Enterprise in the south, all with the cultivar Polka. Plots are equipped with temperature sensors to revisit a possible heat unit model for primocane raspberry.

A raspberry cultivar trial was carried out at the Kaysville research farm from 2011 to 2015. Results from the primocane-cultivar comparison have been included in a manuscript that is currently under review for publication in the International Journal of Fruit Science. Results from the floricane cultivar comparison have been included in an expanded cultivar selection fact sheet that is currently under review by USU Extension.

Sub-objective: Develop alternative crops for diversification opportunities.

- Elderberry. Our first wild selection of blue elderberry (*Sambucus cerulea*) officially released in 2019 as 'AggieBlue™ Rendezvous' was found to be free of known viruses (USDA, Bob Martin). Plants are available for distribution to nurseries, with several Utah native plant nurseries and one Oregon nursery now licensed to propagate. We continue to collect and evaluate additional selections, and plan to release the best ones as part of an "AggieBlue™" series.

- Chokecherry. We have several promising fruiting selections of chokecherry collected from the wild that have been difficult to propagate on their own roots. Tissue culture methods are slow, expensive, and getting TC plants to establish ex vitro is prohibitively slow. We had excellent results in 2019-2020 with a vertical rooting technique. We have been making selections from our seedling fields, as well as seed propagating from some red-fruited wild selections. Stock plants of our best selections tested negative for Western X in 2020.

Publications – research

Black, B.L., T. Maughan, C. Nolasco and B. Christensen. 2019. High tunnels advance primocane raspberry production in a high elevation cold climate. HortScience 54(3): 476-479.

Hansen, S., B. Black, D. Alston T. Lindstrom and S. Olsen. A comparison of nine primocane-fruiting raspberry cultivars for suitability in a high elevation arid climate. Intl. J. Fruit Science. *In review*

Publications - Extension (at http://utahpests.usu.edu, http://fruit.usu.edu, http://tunnel.usu.edu).

Hansen, S., B. Black, D. Alston, T. Lindstrom, T. Maughan and S. Olsen. Selecting summer-bearing raspberry cultivars for Northern Utah. USU Extension - *In review*.

Schumm, Z.R., M. C. Holthouse, D. Alston and L. Spears. 2019. Common Stink Bugs of Utah, USU Extension, pub. ENT-209-19.

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Maughan, T., B. Black, S. Yao and R. Flynn. 2019. Strawberry cultivars for the Intermountain West – research report. USU Extension, Horticulture/Fruit/2019-01.

Maughan, T., B. Black and D. Rowley. 2019. High tunnel strawberry production for early spring harvest. USU Extension, Horticulture/HighTunnel/2019-01pr.

Black, B. and T. Maughan. 2019. High tunnels for earlier production of fall (primocane) raspberries. USU Extension, Horticulture/HighTunnel/2019-02pr.

Maughan, T., B. Black and D. Rowley. 2019. High tunnel strawberry production for late fall harvest. USU Extension, Horticulture/HighTunnel/2019-03.

Report compiled by: Dr. Jayesh Samtani, Hampton Roads Agricultural Research and Extension Center, School of Plant and Environmental Sciences, Virginia Beach, VA.

1. List your research and extension projects under the official NCCC 212 objectives, emphasizing collaborative projects with other researchers. A suggested format is below.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Strawberry:

Study 1. Anaerobic soil disinfestation with different carbon dose rates mixed with yeast in annual hill plasticulture strawberry production.

Authors. Danyang Liu, Jayesh B. Samtani, Charles S. Johnson, Jeffrey Derr, Virginia Tech, VA, and David Butler, Department of Plant Sciences, University of Tennessee, Knoxville, Tennessee, USA.

Study 2. Influence of bacterial endophyte inoculation on strawberry yield in annual hill plasticulture production.

Authors. Robert Chretien[1], Sajeewa Amaradasa[1], Chuansheng Mei[1], Scott Lowman[1], The Institute for Advanced Learning and Research, Danville, VA; Jayesh Samtani and Danyang Liu, Virginia Tech, Virginia Beach, VA.

Study 3. To evaluate yield potential, season extension, and pest susceptibility of strawberry cultivars new to Virginia, in open field and high tunnel, in annual hill plasticulture production systems.

Authors. Jayesh Samtani, Danyang Liu, Aman Rana, Virginia Tech, VA.

2. **How have the results been disseminated to communities of interest? What do you plan to do during the next reporting period to accomplish the goals?**

Data and findings have been disseminated to commercial growers at preplant strawberry meeting which was held virtual in 2020. Studies 1 and 2 should be published or nearing publications at next reporting period. For study 3, we will have more comprehensive report on economic feasibility of annual hill strawberry production in high tunnel environment.

3. Include any data, gemplasm/cultivar descriptions, research results, etc. that you would like to discuss at the meeting. Please keep this brief, highlighting no more than three discussion points within 500 words. Additional information (data tables, abstracts, etc…) can be included in an appendix.

Study 1. Weed control in anaerobic soil disinfestation (ASD) treatments was comparable to fumigated treatment. Presence of yeast improved yield of strawberry crop, with ASD with yeast providing yields comparable to fumigated treatment.

Study 2. Bacillus velezensis, sp. 619 shows promise for field applications in strawberry annual hill plasticulture production.

Study 3. Rocco, Sweet Ann, and Chandler cultivars had the highest total yield in open field, while in high tunnel environment most cultivars except Albion, Flavorfest and Keepsake had similar yield which was higher than the above three cultivars.

4. List retrievable or archived publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications. Please use ASHS style.

Flanagan III, R, J.B. Samtani, M. A. Manchester, S. Romelcyzk, C.S. Johnson, W. Lawrence, and J. Pattison. 2020. On-farm evaluation of strawberry cultivars in coastal Virginia. HortTechnology, https://doi.org/10.21273/HORTTECH04616-20

Samtani, J, S. Das*, and J. Rajevich. 2020. Evaluating supplementary nutrients to improve strawberry fruit quality and yield. International Journal of Fruit Science, 20:1029-1038.

Liu, D., J.B. Samtani, C. Johnson, D. Butler, and J. Derr. 2020. "Weed control assessment of various carbon sources for anaerobic soil disinfestation". International Journal of Fruit Science, 20:1005-1018.

Christman, J. and J.B. Samtani. 2019. A survey of strawberry production practices in Virginia**.** Virginia Cooperative Extension Publication, SPES-150P.

Appendix.

Study 1.

	Total weed counts	Total dry biomass (g)	Added synthetic pre-plant N fertilizer (lb/acre)
Nontreated+yeast	135 a[ab]	1318 a	105
Nontreated with standard preplant fertilizer	150 a	1446 a	60
Nontreated	148 a	1667 a	105
Pic 60 at 175 lb/acre	67 bc	657 b	105
C[c] 4mg/g soil+yeast[d]	44 c	449 b	0
C 4mg/g soil+ preplant fertilizer	60 bc	562 b	60
C 4mg/g soil	68 bc	604 b	0
C 2mg/g soil + yeast	57 bc	615 b	0
C 2mg/g soil	76 b	652 b	0
ANOVA *p*-Value	<0.0001	<0.0001	

[a]Mean values with different letters indicate that the means were significantly different using LSD (α=0.05).
[b]All weed counts were collected from viewing window after ASD, from Jan 2020 to Mar 2020. Weed counting was done when weed canopy covered half of the window area in nontreated controls.
[c] C used was brewer's spent grain and paper mulch. Preplant nitrogen rates for all treatments except nontreated + standard preplant fertilizer and C 4mg/g soil + preplant fertilizer were equal at 105 lb/acre and C. Treatments with standard preplant fertilizer had 60 lb/acre of nitrogen added preplant.
[d]Yeast application rate: 1kg/ha.

Treatment	Marketable yield (g/plant)	Total yield(g/plant)	Pre-plant N fertilizer (lb/acre)
Nontreat+yeast	272 cd[a]	280 cd	105
Nontreat+preplant fertilizer	279 bcd	299 bcd	60
Nontreated	219 d	235 d	105
Fumigant	531 a	597 a	105
C[b] 4mg/g soil+yeast[c]	630 a	643 a	0
C 4mg/g soil + preplant fertilizer	394 b	413 b	60
C 4mg/g soil	382 bc	392 bc	0
C 2mg/g soil + yeast	534 a	548 a	0
C 2mg/g soil	383 bc	395 bc	0

[a] Mean values with different letters indicate that the means were significantly different using LSD (α=0.05).
[b] C used was brewer`s spent grain and paper mulch. Preplant nitrogen rates for all treatments except nontreated + standard preplant fertilizer and C 4mg/g soil + preplant fertilizer were equal at 105 lb/acre and C. Treatments with standard preplant fertilizer had 60 lb/acre of nitrogen added preplant.
[c] Yeast application rate: 1kg/ha.

Study 2.

Cumulative marketable and total yield for the 2018-19 growing season at a farm in Fredericksburg, VA.

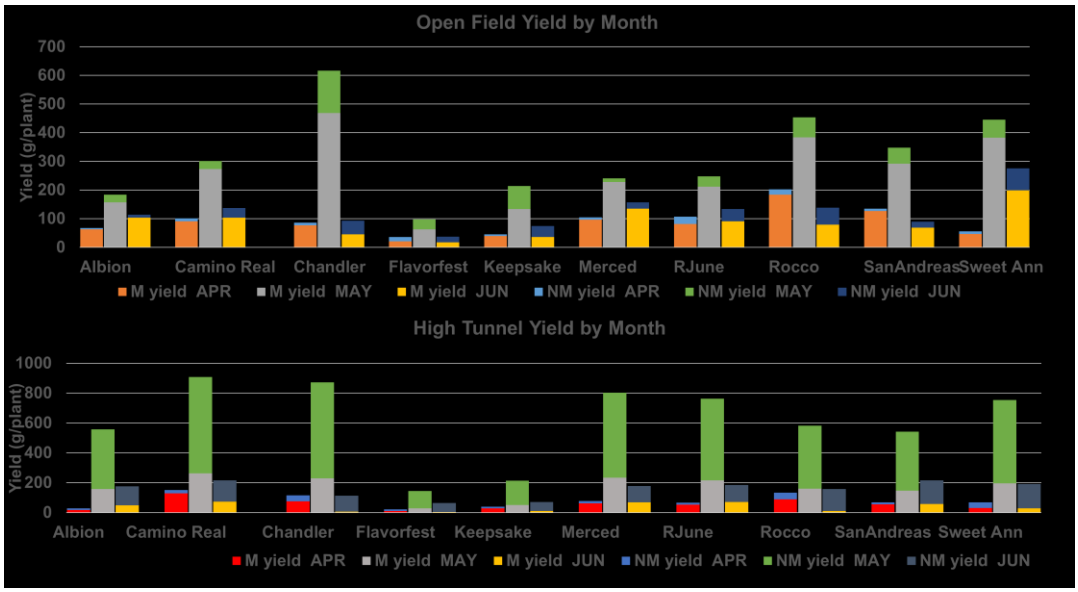
Treatment	Marketable yield (g/plant)	Total Yield (g/plant)
B. *velezensis* IALR 619	270 (+12%)	343 (+11%)
B. *velezensis* IALR 585	231	300
B. *velezensis* IALR 308	220	298
3 B. sp. Combo	206	300
Untreated	241	310
P value, alpha = 0.05	0.2258	0.4007

Cumulative yield for the 2019-20 growing season in Fredericksburg, VA.

Treatment	Marketable yield (g/plant)	Non-marketable yield (g/plant)	Total yield (Market + Non-marketable yield)
B. velezensis IALR 619 (Fall + Spring)	519.6 a	144.2	663.8
B. velezensis IALR 619 (Fall)	463.2 ab	145.5	608.7
Non-treated control	429.8 b	155.5	585.2
$P \leq 0.05$	0.0425	0.1425	0.0655

[a] Mean values with different letters indicate that the means were significantly different using LSD (α=0.05).

Study 3.


Open Field Yield by Month
Yield (g/plant)
700
600
500
400
300
200
100
0
Albion
Camino Real
Chandler
Flavorfest
Keepsake
Merced
RJune
Rocco
SanAndreas
Sweet Ann
M yield APR
M yield MAY
M yield JUN
NM yield APR
NM yield MAY
NM yield JUN
High Tunnel Yield by Month
Yield (g/plant)
1000
800
600
400
200
0
Albion
Camino Real
Chandler
Flavorfest
Keepsake
Merced
RJune
Rocco
SanAndreas
Sweet Ann
M yield APR
M yield MAY
M yield JUN
NM yield APR
NM yield MAY
NM yield JUN

WASHINGTON STATE UNIVERSITY

Email report to mark.hoffmann@ncsu.edu AND rhhassan@ncsu.edu by Oct. 23

1. List your research and extension projects under the official NCCC 212 objectives, emphasizing collaborative projects with other researchers. A suggested format is below.

Title Example: *Evaluation of non-chemical pre-plant soil management alternatives in strawberry.* M. Hoffmann, NC State University, Raleigh NC; S. Fennimore, UC Davis, Salinas CA. F. Louws, NC State University, Raleigh NC;

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Blackberry and Raspberry:

Evaluation of performance of red raspberry selections in the Pacific Northwest. Wendy Hoashi-Erhardt, Washington State University, Bernadine Strik, Pat Jones, Oregon State University, Mary Peterson and Michael Hardigan, USDA-ARS, Corvallis, OR, Michael Dossett, BC Blueberry Council, Abbotsford, BC.

Evaluation of adaptation of red raspberry selections to machine harvesting. Wendy Hoashi-Erhardt, Washington State University, Mary Peterson and Michael Hardigan, USDA-ARS, Corvallis, OR, Michael Dossett, BC Blueberry Council, Abbotsford, BC.

Evaluation of raspberry selections to root rot. Wendy Hoashi-Erhardt, Washington State University, Mary Peterson and Michael Hardigan, USDA-ARS, Corvallis, OR, Michael Dossett, BC Blueberry Council, Abbotsford, BC.

Evaluation of performance of red raspberry cultivars to individually quick frozen processing. Wendy Hoashi-Erhardt, Washington State University, Tom Walters, Walters Ag Research, Anacortes, WA.

Evaluation of performance of advanced red raspberry selections in grower trials in the Pacific Northwest. Wendy Hoashi-Erhardt, Washington State University, Tom Peerbolt and Julie Pond, Northwest Berry Foundation, Portland, OR.

Strawberry:

Evaluation of performance of June-bearing and day-neutral strawberry selections

in the Pacific Northwest. Wendy Hoashi-Erhardt, Washington State University, Bernadine Strik, Pat Jones, Oregon State University, Ted Mackey and Michael Hardigan, USDA-ARS, Corvallis, OR, Michael Dossett, BC Blueberry Council, Abbotsford, BC.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Blackberry and Raspberry:
Polyethylene and biodegradable plastic mulches for improved establishment of raspberry planted as tissue culture transplants. L.W DeVetter, B. Madrid, H. Zhang, C. Miles, C. Benedict, S. Watkinson, Washington State University (WSU), Mount Vernon, WA; I.A. Zasada, USDA-ARS, Corvallis, OR; S. Ghimire, University of Connecticut, Vernon, CT.

Impacts of mycorrhizal fungal inoculants and fertilizer sources on red raspberry. L.W. DeVetter and Q. Lu, WSU, Mount Vernon, WA; and R. Bunn and E. Whitney, Western WA University, Bellingham, WA.

Real-time nutrient analyses of raspberry using petiole sap. L.W. DeVetter, Q. Lu, and C. Miles, WSU, Mount Vernon, WA.

Blueberry & Huckleberry:
Optimizing blueberry pollination to ensure future yields. R. Isaacs and M. Milbrath, Michigan State University, Lansing, MI; L.W. DeVetter, WSU, Mount Vernon, WA; S. Galinato, WSU, Pullman, WA; R. Malinger, University of Florida, Gainesville, FL; A. Melathopoulos, Oregon State University (OSU), Corvallis, OR.

Improving machine harvest efficiency and fruit quality for fresh market blueberry. L.W. DeVetter and Y. Cai, WSU, Mount Vernon, WA; S. Sankaran and C. Zhang, WSU, Pullman, WA; J. Chen, University of Georgia, Athens, GA; W. Yang, OSU, Aurora, OR; F. Takeda, USDA-ARS, Kearneysville, WV; S. Korthuis, B. Foote, and K Van Weerdhuizen, Oxbo, Lynden, WA.

Optimizing nutrient management for organically grown blueberries in eastern Washington. L.W. DeVetter and A. Bhasin, WSU, Mount Vernon, WA; J. Davenport and G. Hoheisel, WSU, Prosser, WA; N. Stacey, WSU, Puyallup, WA.

Determining blueberry cold hardiness in Washington. G. Hoheisel and L. Khot, WSU, Prosser, WA; L.W DeVetter, WSU, Mount Vernon, WA; C. Kogan, WSU, Pullman, WA.

Valuing nitrogen release from high organic matter soils. G. LaHune, C. Sloan, L.W. DeVetter, D. Griffin LaHue, WSU, Mount Vernon, WA.

Management techniques to optimize soil pH and nutrient availability in organic

highbush blueberry grown east of the Cascade Range. S. Lukas, OSU, Hermiston, OR; L.W. DeVetter, WSU, Mount Vernon, WA; J. Davenport and G. Hoheisel, WSU, Prosser, WA; R. Sero and S. Galinato, WSU, Pullman, WA, D. Bryla, USDA-ARS, Corvallis, OR; B. Strik, J. Fernandez-Salvador, D. Sullivan, and K. Trippe, OSU, Corvallis, OR.

VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes. M. Iorizzo, North Carolina State University (NC State), Raleigh, NC; et al. (project team at: https://www.vacciniumcap.org/team).

Strawberry:
Planning grant: Implementation of new technologies and improved end-of-life management for sustainable use of agricultural plastics. L.W. DeVetter, C. Miles, D. Griffin LaHue, WSU, Mount Vernon, WA; M. Flury and G. Yorgey, Puyallup, WA; H. Liu, T. Marsh, K. Englund, S. Galinato, J. Goldberger, T. Chi, M. Perez-Garcia, WSU, Pullman, WA; C. Benedict, WSU, Bellingham, WA; S. Agehara, UF, Wimauma, FL, M. Bolda, University of California Extension, L. McGowen, NC State, Raleigh, NC.

Novel production systems for improved production and disease management in strawberry. L.W. DeVetter, C. Miles, X.M. Wang, L. Tymon, WSU, Mount Vernon, WA; S. Galinato, WSU, Pullman, WA; S. Jung, Cornell University, Ithaca, NY.

Objective 3 - Explore the association between fruit constituents and human health impacts

Blackberry and Raspberry:
Blueberry & Huckleberry:
Grapes:
Elderberry:
Ribes:
Strawberry:
Other small fruit crops:

3. Include any data, gemplasm/cultivar descriptions, research results, etc. that you would like to discuss at the meeting. Please keep this brief, highlighting no more than three discussion points within 500 words. Additional information (data tables, abstracts, etc…) can be included in an appendix.

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Blackberry and Raspberry:

Evaluation of performance of red raspberry selections in the Pacific Northwest. Wendy Hoashi-Erhardt, Washington State University, Bernadine Strik, Pat Jones,

Oregon State University, Mary Peterson and Michael Hardigan, USDA-ARS, Corvallis, OR, Michael Dossett, BC Blueberry Council, Abbotsford, BC.

- Raspberry selections were planted in research plots at WSU-Puyallup in 2017 and 2018, and evaluated for yield and fruit quality for the 2nd and 1st year, respectively, in 2020. Yields and fruit size were smaller than normal for this field, probably due to delayed or missed windows for weed management caused by COVID-related restrictions on labor in 2020.
- Both selection trials will be held over a third year to capture better data in 2021.

Evaluation of raspberry selections to root rot. Wendy Hoashi-Erhardt, Washington State University, Mary Peterson and Michael Hardigan, USDA-ARS, Corvallis, OR, Michael Dossett, BC Blueberry Council, Abbotsford, BC.

- Raspberry, blackberry, and black raspberry selections were planted in research plots in a field at WSU-Puyallup infested with *Phytophthora rubi*, the causal organism for root rot. *Rubus* plants represented advanced selections from the public breeding programs in Oregon, Washington, and British Columbia.
- Four plants of each selection and standard cultivars were planted in 2016, 2017, 2018, and 2019. In the year following planting, the plants were scored for survival. In the 2nd year, plants were rated for vigor on a scale from 0 (plant died) to 5 (vigorous plants).
- WSU 2298, ORUS 4289-4, WSU 2068, and WSU 2377 were the most tolerant red raspberry selections in the trial planted in 2017. WSU 2442, WSU 2377, WSU 2385, WSU 2603 were very tolerant in the trial planted in 2018.

Evaluation of performance of red raspberry cultivars to individually quick frozen processing. Wendy Hoashi-Erhardt, Washington State University, Tom Walters, Walters Ag Research, Anacortes, WA.

- ‘Cascade Premier’ was released in 2018 as an early season cultivar with a midpoint of harvest similar to that of ‘Willamette’ in Washington. It has large, firm fruit with good flavor, good yield, and fruit that machine-harvests well. WSU 2188 is an advanced selection that is recommended for release pending results of its performance in individually quick frozen (IQF) processing. The objective of this project is to compare the new cultivar ‘Cascade Premier’ and WSU 2188 with industry standard cultivars for IQF processing quality, yield, pest tolerance, and winter hardiness.
- Plantings were established in 2019 and 2020, and in the period Sept 2020-Sept 2021, plantings of ‘Cascade Premier’ and WSU 2188 will be evaluated for plant growth and vigor, pest symptoms, overall yield.
- Harvested fruit will be subjected to IQF processing and the resulting product will be evaluated for fruit quality compared with standard cultivars used for IQF.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.

Blackberry and Raspberry:

Polyethylene and biodegradable plastic mulches for improved establishment of raspberry planted as tissue culture transplants. L.W DeVetter, B. Madrid, H. Zhang, C. Miles, C. Benedict, S. Watkinson, Washington State University (WSU), Mount Vernon, WA; I.A. Zasada, USDA-ARS, Corvallis, OR; S. Ghimire, University of Connecticut, Vernon, CT.

- Our multi-year studies have found polyethylene (PE) mulch and biodegradable plastic mulches (BDMs) improve establishment and first-year yields compared to bare ground cultivation in spring-planted, floricane red raspberry planted as tissue culture plugs.
- PE and BDMs in fall/late-summer planted floricane raspberry planted as tissue culture transplants improves weed management, but yield is the same as bare ground cultivation.
- In-soil biodegradation that estimate BDMs deterioration was low (91% of the BDM area remained after 18 month), likely due to cool soil temperatures.

Impacts of mycorrhizal fungal inoculants and fertilizer sources on red raspberry. L.W. DeVetter and Q. Lu, WSU, Mount Vernon, WA; and R. Bunn and E. Whitney, Western WA University, Bellingham, WA.

- Commercial mycorrhizae did not increase raspberry growth nor impact nutrient uptake in a greenhouse experiment; growth measurements more impacted by fertilizer treatment than mycorrhizal inoculants
- Although overall colonization of mycorrhizae in roots was low, plants formed more mycorrhizae with MYKOS (Xtreme Gardening, Gilroy, CA) and Bio-Organics (Bio-Organics, LLC, New Hope, PA) than Endo-Mycorrhizae Mycorrhizal Applications, Grants Pass, OR
- A separate experiment showed some inoculants did confer some increased tolerance to Phytophtora root rot (*Phytophora rubi*), but not root lesion nematodes (*Pratylenchus penetrans*).

Real-time nutrient analyses of raspberry using petiole sap. L.W. DeVetter, Q. Lu, and C. Miles, WSU, Mount Vernon, WA.

- Nitrate and calcium sap results in primocanes of ‘Meeker’ raspberry were positively correlated with tissue nitrogen and calcium, respectively, between mid-July and late Aug (15 July-25 Aug.). However, the correlation was weak (R^2=0.73; *P* value = 0.0007 for nitrate; R^2=0.41; *P* value = 0.003 for calcium).
- Potassium sap results were negatively correlated to tissue K content during the season
- Nitrate and potassium sap analysis have the potential to be used for rapid monitoring of these nutrients, but further validation is needed.

Blueberry & Huckleberry:
Optimizing blueberry pollination to ensure future yields. R. Isaacs and M. Milbrath, Michigan State University, Lansing, MI; L.W. DeVetter, WSU, Mount Vernon, WA; S. Galinato, WSU, Pullman, WA; R. Malinger, University of Florida, Gainesville, FL; A. Melathopoulos, Oregon State University (OSU), Corvallis, OR.

- This is a new, specialty-crop research project
- Activities we will accomplish within the 4-year project period include: compare and conduct cost-benefit analyses of different strategies for honey bee pollination; determine pollination requirements and pollinator attraction across new and existing cultivars; determine how variable weather conditions affect blueberry pollination; develop predictive models of pollination, fruit set, and yield for development of a Pollination Planner; and deliver information on improved blueberry pollination to the industry.

Improving machine harvest efficiency and fruit quality for fresh market blueberry. L.W. DeVetter and Y. Cai, WSU, Mount Vernon, WA; S. Sankaran and C. Zhang, WSU, Pullman, WA; J. Chen, University of Georgia, Athens, GA; W. Yang, OSU, Aurora, OR; F. Takeda, USDA-ARS, Kearneysville, WV; S. Korthuis, B. Foote, and K Van Weerdhuizen, Oxbo, Lynden, WA.

- Additional machine harvest trials using a modified OXBO 7440 were done in 2020 and some of these machines have been purchased by growers.
- Resultant fruit quality of the modified harvesters is generally improved compared to traditional machine harvest but is not equivalent to hand harvested fruit. Proper harvest timing and postharvest management is essential to achieve quality fresh market fruit, which is a knowledge gap among growers shifting from processed to fresh market production.
- Food safety and sanitization work of new, harvester surfaces was delayed due to the pandemic, but should be produced in 2021.

Optimizing nutrient management for organically grown blueberries in eastern Washington. L.W. DeVetter and A. Bhasin, WSU, Mount Vernon, WA; J. Davenport and G. Hoheisel, WSU, Prosser, WA; N. Stacey, WSU, Puyallup, WA.

- Eastern Washington is a unique blueberry growing environment with soils that are low in organic matter, calcareous, and naturally high in pH (>7.8). They also have access to different organic fertilizer sources compared to other important production regions in the Pacific Northwest. However, eastern Washington is a very important contributor to the national organic blueberry market. The industry lacks information on organic nutrient management for their unique environment and this project seeks to generate this needed information.
- Research evaluating optimal organic nitrogen fertilizer sources and rates has been ongoing since 2018. Fish emulsion, WISErganic (a liquid fertilizer made from digested food products), blood meal, and a combination of blood meal and WISErganic at 50, 100, and 150 lbs/acre N have been applied to ‘Duke’ at a grower cooperator site. No statistically

significant effects on yield nor fruit quality have been observed to date, but plants fertilized at the low rate with fish emulsion are trending to have greater yields. This experiment is ongoing.

- Another experiment assessed the timing of organic fertilizer nitrogen cut-off times in an early fruiting cultivar ('Duke'). Treatments were 100, 80, 70 or 60% of the nitrogen fertilizer (125 lbs/acre; applied as WISErganic) applied pre-harvest and the remaining 0, 20, 30, or 40% applied post-harvest. No yield nor fruit quality effects have been observed over the three years of the experiment. Cold-hardiness decreased during fall acclimation with increasing lateness of fertilizer applications, however plants remained cold-hardy to temperatures below the average monthly temperature minimums for the region.

Determining blueberry cold hardiness in Washington. G. Hoheisel and L. Khot, WSU, Prosser, WA; L.W DeVetter, WSU, Mount Vernon, WA; C. Kogan, WSU, Pullman, WA.

- Cold hardiness models are being developed for western and eastern Washington using 'Duke', 'Draper', 'Liberty', and 'Aurora'. Models for 'Duke' and 'Liberty' are more advanced and should be validated as a β version on WSU AgWeather Net soon. Cold hardiness work for 'Draper' and 'Aurora' is ongoing with more field assessments scheduled for winter 2020/2021.
- Relative water content may improve cold hardiness models, but validation is still underway.
- Khot and Hoheisel are working on developing a nondestructive method for sensing bud damage using hyperspectral imaging. Work is ongoing.

Valuing nitrogen release from high organic matter soils. G. LaHune, C. Sloan, L.W. DeVetter, D. Griffin LaHue, WSU, Mount Vernon, WA.

- Soil organic matter content varies from 3-60% in commercial blueberry fields in western Washington. Some growers struggle to manage fertility in these fields due to unpredictable release of nitrogen through mineralization.
- Incubation studies are underway to quantify nitrogen mineralization from histosols with varying soil organic matter content.
- Four on-farm experiments were established in 2019 in 'Duke' fields with a range in soil organic matter content (i.e., high, medium, and low). Fertilizer rate was adjusted in a randomized complete block design experiment within each site to assess plant response to these different rates within a range of soil organic matter concentrations. No yield, tissue nutrient, nor fruit quality effects have been observed to date, but work is ongoing.

Management techniques to optimize soil pH and nutrient availability in organic highbush blueberry grown east of the Cascade Range. S. Lukas, OSU, Hermiston, OR; L.W. DeVetter, WSU, Mount Vernon, WA; J. Davenport and G. Hoheisel, WSU, Prosser, WA; R. Sero and S. Galinato, WSU, Pullman, WA, D.

Bryla, USDA-ARS, Corvallis, OR; B. Strik, J. Fernandez-Salvador, D. Sullivan, and K. Trippe, OSU, Corvallis, OR.

- Growers in eastern Washington and Oregon grow blueberry on soils with native soil pH of >7.8 and alkaline irrigation water. There is concern about effective and long-term management of soil pH for sustained production in these systems. A field project was recently established in Hermiston, OR, and is testing different methods to acidify blueberry soils. Treatments include wet and dry applications of prilled sulfur (incorporated or surface applied), micronized sulfur, and their combinations as pre- and post-plant applications.
- High soil temperatures in the region can also lead to rapid oxidation and loss of soil organic matter. Traditional sources of organic matter (Douglas fir sawdust) is also limited in availability east of the Cascade Range. However, the region has substantial amounts of grape pomace due to the grape and wine industry. A separate greenhouse experiment in Mount Vernon is testing the suitability and acidification requirements of composted grape pomace as a soil amendment in organic blueberry. Work was delayed due to the pandemic, but is ongoing.
- Biochar made from crop prunings is also being tested as a source of organic matter.

VacciniumCAP: Leveraging genetic and genomic resources to enable development of blueberry and cranberry cultivars with improved fruit quality attributes. M. Iorizzo, North Carolina State University (NC State), Raleigh, NC; et al. (project team at: https://www.vacciniumcap.org/team).

- This multi-institutional project is being led by Massimo Iorizzo.
- According to the website, "*VacCAP is a nationwide coordinated transdisciplinary project focused on addressing major bottlenecks limiting the growth of the U.S. Vaccinium industry by developing and implementing marker assisted selection (MAS) capacity in breeding programs. Completing this will enable breeders to select and pyramid fruit characteristics that positively contribute to fruit quality and market value*."
- This project brings together the Vaccinium breeding community and should result in valuable knowledge, technologies, and partnerships that will accelerate and improve breeding efforts for blueberry and cranberry.

Strawberry:

Planning grant: Implementation of new technologies and improved end-of-life management for sustainable use of agricultural plastics. L.W. DeVetter, C. Miles, D. Griffin LaHue, WSU, Mount Vernon, WA; M. Flury and G. Yorgey, Puyallup, WA; H. Liu, T. Marsh, K. Englund, S. Galinato, J. Goldberger, T. Chi, M. Perez-Garcia, WSU, Pullman, WA; C. Benedict, WSU, Bellingham, WA; S. Agehara, UF, Wimauma, FL, M. Bolda, University of California Extension, L. McGowen, NC State, Raleigh, NC.

- This planning grant met remotely in 2020 and is working on a full SCRI proposal to test, develop, and deliver new technologies that will improve

end-of-life management of agricultural plastics with an emphasis on mulches in strawberry systems.

- The project team and in partnership with Western SARE (project led by Miles) has contributed to many extension outputs regarding end-of-life management and biodegradable plastics. Training opportunities for your stakeholders or students on biodegradable plastics are available for free. Contact Lisa DeVetter (lisa.devetter@wsu.edu) or Carol Miles (milesc@wsu.edu).
- If our pending SCRI CAP proposal is successful, we would like to partner with other institutions to deliver information about the project to undergraduate and graduate students, as they are the next generation of scientists that have opportunities to address improved management of agricultural plastics.

Novel production systems for improved production and disease management in strawberry. L.W. DeVetter, C. Miles, X.M. Wang, L. Tymon, WSU, Mount Vernon, WA; S. Galinato, WSU, Pullman, WA; S. Jung, Cornell University, Ithaca, NY.

- Biodegradable plastic mulches (BDMs) are a promising alternative to traditional plastic mulches, yet are 2-3 times more expensive. While cost savings from labor for removal and disposal are eliminated with BDMs, cost concerns nevertheless have the potential to limit adoption of this technology. In small, diverse cropping systems, double-cropping could extend the value of BDMs if the crop production and quality is maintained. We have established a field experiment where 'Albion' strawberry is being double cropped with head lettuce. Project results are pending for the first year of the trial.
- BDMs degrade on the surface, resulting in losses in tension and elasticity over time. This may impact splash dispersal of fungal and/or bacterial spores carried in rain droplets. We are testing this hypothesis through global splash dispersal studies and more refined bioassays in collaboration with a plant pathologist (Tymon) and bio-fluid mechanic scientist (Jung).

4. List retrievable or archived publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications. Please use ASHS style.

Peer-reviewed articles, Refereed:

Zhang, H., C. Miles, M. Flury, H. Liu, and L.W. DeVetter. 2020. Soil-biodegradable plastic mulches undergo minimal in-soil degradation in a perennial raspberry system after 18 months. Horticulturae. 6(3). doi.org/10.3390/horticulturae6030047.

Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, H. Liu, and L.W. DeVetter. 2020. Plastic mulches improved plant growth and suppressed weeds in late summer-planted floricane raspberry. HortScience 55:565–572.

Gan, W., H. Zhang, N. Bostan, and L.W. DeVetter. 2020. Pollen germination and growth rates differ among cultivars of northern highbush blueberry (*Vaccinium corymbosum*). Journal of the American Pomological Society 74: 66-75.

Zhang, H., L.W. DeVetter, E. Scheenstra, and L.W. DeVetter. 2020. Weed pressure, yield, and adhesion of soil-biodegradable mulches with pie pumpkin (*Cucurbita pepo*). HortScience. 55: 1014–1021.

Alegea, F.P., G.J. Miitoa, L.W. DeVetter, H. Tao, and P.M. Ndegwa. 2020. effects of blending dairy manure compost and canola meal on pellets quality and nutrients concentrations. Journal of Cleaner Production. *In press*.

Rudolph, L.W., I.A. Zasada, C. Hesse, and L.W. DeVetter. 2020. Effects of annual and perennial alleyway cover crops on physical, chemical, and biological properties of soil quality in Pacific Northwest red raspberry. HortScience 55:344-352.

Websites:
DeVetter, L.W. and C.A. Miles. 2020. Plastic mulches in Small Fruit Production: https://smallfruits.wsu.edu/plastic-mulches/.

Theses:
Bhasin, A. 2020. Evaluating organic nitrogen fertilizer sources, rates, and timing in northern highbush blueberry grown in high pH soils of eastern Washington. MS Thesis, Washington State University, Pullman, WA.

Zhang, H. 2020. Tissue culture red raspberry production systems with plastic mulches. PhD Dissertation, Washington State University, Pullman, WA.

1. List your research and extension projects under the official NCCC 212 objectives, emphasizing collaborative projects with other researchers. A suggested format is below.

Objective 1 - Develop improved small fruit germplasm through cooperative breeding and evaluation programs:

Blackberry and Raspberry:

Continuing to evaluate performance of blackberry and raspberry selections until vice-Finn position is filled. C. Finn, USDA-ARS-HCRU, Corvallis OR; B. Strik, Oregon State University, Corvallis OR; M. Hardigan, USDA-ARS-HCRU, Corvallis OR; P. Moore, Washington State University, Puyallup WA; M. Dossett, Agri-Food Research Centre, Agriculture and Agri-Food Canada, Agassiz, BC Canada; N. Bassil, USDA-ARS-NCGR, Corvallis OR; M. Peterson, USDA-ARS, Corvallis OR; R. Martin, USDA-ARS-HCRU, Corvallis OR; J. Lee, USDA-ARS-HCRU, Parma ID.

'Twilight' (ORUS 4370-1; USPP 30,879) semi-erect blackberry released and patented 2019. C. Finn, USDA-ARS-HCRU, Corvallis OR; B. Strik, Oregon State University, Corvallis OR; B. Yorgey, OSU, Corvallis OR; M. Peterson, USDA-ARS, Corvallis OR; P. Jones, OSU, Aurora, OR; J. Lee, USDA-ARS-HCRU, Parma ID; N. Bassil, USDA-ARS-NCGR, Corvallis OR; R. Martin, USDA-ARS-HCRU, Corvallis OR.

Blueberry & Huckleberry:

Continuing to evaluate performance of blueberry selections until vice-Finn position is filled. C. Finn, USDA-ARS-HCRU, Corvallis OR; B. Strik, Oregon State University, Corvallis OR; M. Hardigan, USDA-ARS-HCRU, Corvallis OR; N. Bassil, USDA-ARS-NCGR, Corvallis OR; T. Mackey, USDA-ARS, Corvallis OR; R. Martin, USDA-ARS-HCRU, Corvallis OR; J. Lee, USDA-ARS-HCRU, Parma ID.

Objective 2 - Develop practices for small fruit production tailored for climatic and market needs of growers.
n.a.

How have the results been disseminated to communities of interest?
What do you plan to do during the next reporting period to accomplish the goals?

3. Include any data, germplasm/cultivar descriptions, research results, etc. that you would like to discuss at the meeting. Please keep this brief, highlighting no more than three discussion points within 500 words. Additional information (data tables, abstracts, etc…) can be included in an appendix.

n.a.

4. List retrievable or archived publications arising from your collaborative research projects including journal articles, book chapters, review articles, theses, proceedings, and extension publications. Please use ASHS style.

Bradish, C.M., J.M. Bushakra, L. Robbins, E. Karaaoac, S. Teo, J.L. Willard, P. Perkins-Veazie, J. Lee, J. Scheerens, C. Weber, M. Dossett, N.V. Bassil, C.E. Finn, G. Fernandez, G. 2020. Standardized phenotyping in black raspberry. J. Amer. Pomol. Soc. 74:2-17.

Bushakra, J.M., L.A. Alice, K.A. Carter, M. Dossett, J.C. Lee, A. Liston, R. Meiers, C. Mulch, A.M. Nyberg, J.R. Clark, C.E. Finn, N.V. Bassil, and K.E. Hummer. 2020. Status of *Rubus* germplasm at the US National Clonal Germplasm Repository in Corvallis, Oregon. Acta Hort. 1277:121-128.

Carter, K., J.D. Zurn., N.V. Bassil, C.E. Finn, and K.E. Hummer. 2019. The importance of being 'Boysen': examining genotypic variation with simple sequence repeat markers. J. Amer. Pomol. Soc. 73:47-52.

Castillejo, C., V. Waurich, H. Wagner, R. Ramos, N. Oiza, P. Muñoz, J.C. Triviño, J. Caruana, Z. Liu, N. Cobo, M.A. Hardigan, S. Knapp, J.G. Vallarino, S. Osorio, C. Martín-Pizarro, D. Pose, T. Toivainen, T. Hytonen, Y. Oh, C.R. Barbey, V.M. Whitaker, S. Lee, K. Olbricht, J.F. Sánchez-Sevilla, and I. Amaya. 2020. Allelic Variation of MYB10 is the Major Force Controlling Natural Variation of Skin and Flesh Color in Strawberry (Fragaria spp.) fruit. Plant Cell tpc.00474.2020. doi:10.1105/tpc.20.00474.

Moore, P.P., W. Hoashi-Erhardt, C.E. Finn, R.R. Martin, and M. Dossett. 2019. 'WSU 2166' red raspberry. HortScience 54:564-4567.

Mulch, C., N.V. Bassil, C.E. Finn, M. Dossett, and K.J. Vining. Development of a robust RNA extraction protocol for black raspberry. Acta Hort. 1277:113-120.

Farneti, B., F. Emanuelli, L. Giongo, P. Toivonen, M. Iorizzo, K. Folta, and C. Finn. Editorial: interdisciplinary approaches to improve quality of soft fruit berries. Frontiers Plant Sci. 11: article number 592222.

Feldmann, M.J., M.A. Hardigan, R.A. Famula, C.M. López, A. Tabb, G.S. Cole, and S.J. Knapp. 2020. Multi-dimensional machine learning approaches for fruit shape phenotyping in strawberry. Gigascience 9. doi:10.1093/gigascience/giaa030.

Finn, C.E. 2019. United States Plant Patent Number 30,062. Blackberry plant named 'Galaxy'.

Finn, C.E. 2019.United States Plant Patent Number 30,063. Blackberry plant named 'Hall's Beauty'.

Finn, C.E. 2019. United States Plant Patent Number 30,448. Blackberry plant named 'Eclipse'.

Finn, C.E. 2019. United States Plant Patent Number 30,879. Blackberry plant named 'Twilight'.

Finn, C.E., B.C. Strik, T.A. Mackey, P.A. Jones, N.V. Bassil, and R.R. Martin. 2019. 'Echo' ornamental reflowering blueberry. HortScience 54:368-370.

Finn, C.E., B.C. Strik, B.M. Yorgey, M.E. Peterson, P.A. Jones, J. Lee, N.V. Bassil, and R.R. Martin. 2019. 'Hall's Beauty' thornless trailing blackberry. HortScience 54:371-376.

Finn, C.E., B.C. Strik, B.M. Yorgey, M.E. Peterson, P.A. Jones, J. Lee, N.V. Bassil, and R.R. Martin. 2020. 'Twilight' thornless semi-erect blackberry. HortScience 55:1148-1152.

Finn, C.E., B.C. Strik, B.M. Yorgey, M.E. Peterson, P.A. Jones, G. Buller, J. Lee, N.V. Bassil, and R.R. Martin. 2020. 'Galaxy' thornless semierect blackberry. HortScience 55:967-971.

Finn, C.E., B.C. Strik, B.M. Yorgey, M.E. Peterson, P.A. Jones, G. Buller, S. Serçe, J. Lee, N.V. Bassil, and R.R. Martin. 2020. 'Eclipse' thornless semi-erect blackberry. HortScience 55:749-754. [*Journal issue cover photo*]

Finn, C.E., M.E. Peterson, J.R. Clark, G.E. Fernandez, H.K. Hall, M.L. Worthington. 2020. Merging blackberry germplasm pools and moving previously unutilized species into commercially viable selections. Acta Hort. 1277:47-54.

Hardigan, M.A., M.J. Feldmann, A. Lorant, K.A. Bird, R. Famula, C. Acharya, G. Cole, P.P. Edger, and S.J. Knapp. 2020. Genome synteny has been conserved among the octoploid progenitors of cultivated strawberry over millions of years of evolution. Front. Plant Sci. 10:1789. doi:doi.org/10.3389/fpls.2019.01789.

Hon, T., K. Mars, G. Young, Y.-C. Tsai, J.W. Karalius, J.M. Landolin, N. Maurer, D. Kudrna, M.A. Hardigan, and C.C. Steiner. 2020. Highly accurate long-read HiFi sequencing data for five complex genomes. bioRxiv.

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Samtani, J.B., C.R. Rom, H. Friedrich, S.A. Fenimore, C.E. Finn, A. Petran, R.W. Wallace, M.P. Pritts, G. Fernandez, C. Chase, C. Kubota, and B. Bergefurd. 2019. The status and future of the strawberry industry in the U.S. HortTechnology 29:11-24.

Whitaker, V.M., S.J. Knapp, M.A. Hardigan, P.P. Edger, J.P. Slovin, N. V Bassil, T. Hytönen, K.K. Mackenzie, S. Lee, S. Jung, and others. 2020. A roadmap for research in octoploid strawberry. Hortic. Res. 7:1–17.

Willman, M., J.M. Bushakra, N.V. Bassil, C.E. Finn, M. Dossett, P. Perkins-Veazie, C.M. Bradish, G.E. Fernandez, C.A. Weber, J. Scheerens, L. Dunlap, J. Fresnedo-Ramírez. 2020. Genetic analysis of drupelet count in black raspberry (*Rubus occidentalis*). Acta Hort. 1277:65-72.

Worthington, M.L., R. Aryal, N.V. Bassil, D. Mead, G.E. Fernandez, J.R. Clark, F. Fernández-Fernández, C.E. Finn, K.E. Hummer, H. Ashrafi. 2020. Development of new genomic resources and tools for molecular breeding in blackberry. Acta Hort. 1277:39-46

Zurn, J., M. Driskill, S. Jung, D. Main, M.H. Yin, M.C. Clark, L. Cheng, H. Ashrafi, E. Aryal, J.R. Clark, M. Worthington, C.E. Finn, C. Peace, A.F. Iezzoni, and N. Bassil. 2020. A Rosaceae family-level approach to identify loci influencing soluble solids content in blackberry for DNA-informed breeding. G3-Genes Genomic Genetics. In press. DOI: 10.1534/g3.120.401449.

Zurn, J.D. R. Meiers, J. Ward, C.E. Finn, M. Dossett, and N.V. Bassil. 2020. Identifying variation in red raspberry MLO genes thought to provide resistance to powdery mildew. Acta Hort. 1277:25-32.

Zurn, J.D. K.L. Ivors, G.S. Cole, S.J. Knapp, K.E. Hummer, J.F. Hancock, C.E. Finn, and N.V. Bassil. 2020. Assessed cultivated strawberries and the *Fragaria* supercore for resistance to soilborne pathogens. J. Amer. Pomol. Soc. 74:18-23.