FINAL PROJECT REPORT **YEAR:** 2017
WTFRC Project Number: N/A

Project Title: Programs to increase packouts of apples

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Cooperators:

- WTFRC internal program: Manoella Mendoza, Mackenzie Perrault, Felix Schuhmann
- Others: Rob Blakey (former WSU), Grower collaborators, WTFRC seasonal crew and interns, Glade Brosi/Hannah Walters (Stemilt), Garrett Bishop (GS Long)
- WA 38 starch scale review panel: Lauren Gonzalez (Kershaw), Suzanne Bishop (Allan Bros.), Jim Mattheis (USDA-ARS), Kate Evans + team (WSU-Wenatchee), Bill Wolk (BC)

Other funding sources
Supplies and fruit were donated by industry cooperators (approx. value: $2,500); GS Long covered the cost for mineral analysis for WA 38

Europe trip: WTFRC internal travel ($ 2,500); Chile trip: sponsored by Dr. Torres program (valued at $3,000)

Budget 1
Organization Name: WTFRC **Contract Administrator: Kathy Coffey**
Telephone: 509 665 8271 **Email address: Kathy@treefruitresearch.com**

Item	2016	2017 (projected)	2017 (actual)*
Salaries	6,785	6,785	2,247
Salary benefits	3,401	4,301	742
Wages	15,734	7,800	9,548
Wage benefits	5,156	2,643	4,703
RCA rental	1,800	1,800	0
Equipment + supplies	268	300	210
Travel	167	500	0
Reimbursements	---	---	0
Total net costs	**33,311**	**24,129**	**19,466**

Footnotes:
2017 actual budget is based on the calendar year 2017 (July 1, 2016-June 30, 2017); July 1- Dec. 2017 (not shown)
Salaries*: incl. proportional time spent on outlined projects for Mendoza (4%); NOT included 6% of Hanrahan's time
Supplies: experimental fruit, storage boxes and trays donated
RCA rental: numbers based on fiscal year (@ approx. $6,300/room/year)
Reimbursements: monetary contributions by chemical suppliers, if applicable

NOTE: This is a final report. All internal program research projects will require new proposals to the WTFRC board in March 2018.

OBJECTIVES[A]

1. Document Honeycrisp fruit quality in local store displays.
2. Test new tools to determine fruit quality parameters (no work in 2017).
3. Serve on WSU Tree Fruit Extension team as postharvest specialist (2017: DISORDER GUIDE, WA 38, POSTHARVEST FRUIT SCHOOL).
4. Field test methods to induce bitter pit in Honeycrisp.
5. Compare and document fruit quality of Premier Honeycrisp and Honeycrisp strains (NEW 2017).
6. Expand collaborative efforts with other research programs working on fruit quality management.

[A]seasonal adjustment of objectives based on industry feedback and Hanrahan program capacity in 2017.

SIGNIFICANT FINDINGS

Objective 1: With Honeycrisp currently sourced from several countries, consistently good eating quality in the second part of the storage season (February to August) remains of concern.

Objective 3: WA38 develops two predominant starch patterns, which appear in a 6:4 ratio. WA38 converts starch very slow back to sugar. The reaction time for the iodine solution to color the starch crystals is significantly longer compared to other industry specific varieties.
A total of 7,833 photographs of 106 defects were created during 2017. The WSU CAHNRS Video & Photography Department will help to produce the final publications. These will be: (i) an online guide with rotatable photographs with annotations and descriptions, and (ii) hard copy with photographs and defect description.
A Postharvest fruit school was developed by the Extension team to be held in two locations (Prosser, Wenatchee) in March of 2018.

Objective 4: The Ethephon method delivered the fastest and best results in 2017. All methods predict best when the percentage of bitter pit affected fruit is below 10% before harvest, with no more than 25% of the remaining fruit developing symptoms in subsequent storage.

Objective 5: Premier Honeycrisp displays harvest maturity, storage life, and eating quality after storage similar to other common Honeycrisp strains/selections. Based on preliminary results, the fruit was less prone to chilling injury, but bitter pit and stem bowl splits may occur.

Objective 6: We continue to build productive and dynamic research and outreach partnerships with a number of cooperators on projects relevant to pre and postharvest fruit quality management.

METHODS

Supermarket survey: Eight Yakima supermarkets were visited monthly from June until August 2017. Visual quality and supply of fruit was determined.

Induced bitterpit: Five orchards were selected (3 orchards = all methods, 2 orchards = PennState method [https://extension.psu.edu/fruit-disorders-new-tool-to-assess-the-potential-for-bitter-pit-in-honeycrisp]). Before the apples were harvested, the amount of Bitter Pit (BP) was assessed per tree. All apples were harvested between the 2nd and 5th wire on the west or south side of the tree. The apples were picked a few days prior to first commercial harvest. For the PennState method five typical terminal shoot measurements were taken. In the first three orchards, a total of 270 apples per orchard (passive method: 40, Ethephon method: 40, hot water method: 40, PennState method: 20, untreated control (UTC): 120 and maturity sample: 10) were harvested. In the other two orchards, 150

apples per orchard were sampled (PennState method: 20, control: 120 and maturity sample: 10). 20 representative trees were selected in each orchard.
Within 2 hours of harvest, fruit was prepared as follows:

1. All fruit were washed in 77°F (25°C) tab water.
2. The fruit were left to air dry.
3. Hot Water Method:
   a. A cooler was filled with hot water and adjusted to ~120°F (49°C).
   b. The apples were submerged into the hot water and held under water with warmed up hard plastic ice packs. If the temperature dropped below 115°F (46°C), hot water (~125°F) was added.
   c. After 30 minutes, the samples were taken out of the water and laid to dry on trays layered with paper towels.
4. Ethephon Method:
   a. A plastic box was filled with 2 gal (7.6 l) of water (temperature: 77°F) and 0.5 oz (15 ml) of Ethephon (1 gal= 0.25 oz) was mixed in.
   b. Every apple was dipped (2 sec) in the prepared solution.
   c. The samples were laid to dry on trays layered with paper towels.
5. Passive Method:
   a. No further steps were added to this method.
6. All apples from these three methods were placed in apple boxes and stored at room temperature for 3 weeks.
7. The fruit was evaluated after one, three, five, eight, eleven, fourteen and twenty-one days.
8. PennState Method:
   a. A commercial fruit dryer was preheated to 160°F (71°C).
   b. A fruit peeler was used to remove a 3/8" wide (1 cm) strip of peel from around the circumference at the calyx end of the fruit.
   c. Samples were put on a drying tray and dried for 9 hours at 160°F.
   d. After 9 hours the samples were stored in Ziploc® bags and sent to a laboratory for a nutrition analysis.

The UTC fruit was stored following the Honeycrisp storage recommendations [http://treefruit.wsu.edu/article/honeycrisp-storage-recommendations-revisited/] and apples were evaluated after 2, 4, 6, 8 and 12 weeks of cold storage.

WSU Tree Fruit Extension team:

WA 38 starch scale:

WA38 apples were picked in four locations (Roza, Prosser, Quincy, Sunrise). Before the harvest in week 10/09 - 10/12/2017 sample fruit were picked in the orchard. After harvest, the fruit was stored at 33°F. In mid-November, a sample of 40 fruit was stored at room temperature, to advance maturity. Apples were prepared and pictures taken between 9/25/2017 and 11/29/2017.
To prepare the apples:

1. The apples were cut in half through the equator.
2. The freshly cut apple surface was dipped in iodine solution to cover flesh.
3. After 30 mins the pattern was fully developed and the surface was then dried with a paper towel.
4. A picture was taken under consistent light environment (i.e. a photo box).
5. The pictures were evaluated and grouped.

We have used an industry focus group (field men, QC personnel, R&D, scientists) to gather feedback on various stages of the actual starch scale and on potential best layout options.

Apple Disorder guide:

During the 2016-17 storage season samples were collected from local packers. Fruit was then grouped by variety, disorder, and severity of symptoms. TJ Mullinax of the Good Fruit Grower photographed samples of fruit including views of external and internal symptoms, and additional photographs on a rotating platform.

Quality of HC strains and early maturating selection:
Eight orchards of Honeycrisp were selected including three different strains (Standard, Royal Red, and Firestorm) and Premier Honeycrisp (early maturing selection). All fruit was harvested at commercial maturity. A sample of 40 fruit each of Premier HC was stored for three months in a 33°F room or fruit was stored following the Honeycrisp storage protocol (see http://treefruit.wsu.edu/news/honeycrisp-storage-recommendations-revisited/). Fruit was inspected weekly for four weeks to determine changes in maturity and defects

The remainder seven orchards were all stored as untreated control (UTC) at 33°F from one month to three months depending on harvest date. After storage, fruit quality of all samples was determined.

All apples in each sample were evaluated externally for disorders rendering them culls in a commercial setting. Twenty-five apples were cut in order to determine any internal disorders. Taste was rated 1-5 using a scale specific to this experiment on four apples from each sample (1=immature flavor, 2=mature flavor, 3=over mature, 4=bland (no flavor, no detectable off flavor), and 5=off flavor (a-typical taste profile)).

RESULTS & DISCUSSION

I*n 2017, the fruit quality program has continued to focus part of its effort on Honeycrisp fruit quality. Based on the membership of WTFRC staff in the WSU Tree Fruit Extension team, Hanrahan added WA38 and leadership in Postharvest Fruit School organizing team.*

Supermarket survey

The increasing production of Honeycrisp apples has resulted in the variety being available to consumers more months of the year, but those apples may not always be of the highest quality. In 2012 the Washington Tree Fruit Research Commission (WTFRC) began a survey to assess how long Honeycrisp apples remain on the retail shelf locally throughout the year and, more importantly, monitor the eating quality of those apples.
Last season, eight Yakima area supermarkets were visited once a month from June until August 2017. In the months of June and July, all locations continued to carry fruit from the previous year's harvest, with one store offering Chilean and New Zealand Honeycrisp apples. By August, the supply of Honeycrisp fruit was 75% foreign market supply (Chile, New Zealand). In July of 2017 we observed the first supply of fruit grown in New Zealand (Table 1).
As the current harvest season approached, the external quality of the fruit started to vary within the supermarkets. They ranged from good color and no defects in most locations (until June 2017) to half the locations supplying fruit of inferior visual appearance in August (not shown). In summary, the 2016-17 storage season proved to be the second time we documented a year-round Honeycrisp supply in local supermarkets, but during the summer visual appearance of fruit started to drop.

With Honeycrisp currently sourced from several countries (Table 1), consistently good eating quality in the second part of the storage season (February to August) remains of concern (Table 2). If consumers are having inconsistent eating experiences from good to off flavor, repeat sales could be impacted negatively. It appears that this issue has remained a constant struggle over the past six storage seasons.

Table 1: Supply of Honeycrisp in local Yakima supermarkets by country of origin.

Sources of fruit								
Year	January	February	March	April	May	June	July	August
2012	US	US	US	-	-	-	-	-
2013	US	US	US	US	US	-	-	-
2014	US	US	US	US	US C	US C	-	-
2015	US	US	US	US	US	US C	US C	-
2016	US	US	US	US	US	US	US	US C
2017	US	US	US	US	US	US C	US C N	US C N

Note: US = USA, C = Chile, N = New Zealand

Table 2: Summary of Honeycrisp apples flavor of eight Yakima supermarkets from 2012-2016.

Percentage good flavor								
Year	January	February	March	April	May	June	July	August
2012	-	-	0	-	-	-	-	-
2013	-	-	14	-	-	-	-	-
2014	-	29	43	67	43	0	-	-
2015	-	14	14	57	33	44	20	-
2016	-	42	25	45	29	33	44	42

Induced bitter pit

All UTC fruit showed a similar pattern in developing bitter pit. After 4-8 weeks of exponential rise in bitter pit incidence, the expression of additional bitter pit in remaining fruit slowed down and eventually approached zero (see Figure 1). After a 12-week storage period, Honeycrisp apples from orchard 1 showed in average 10 apples with symptoms (25%), from orchard 2, 26 apples (64%) and from orchard 3, 19 apples (48%) had developed bitter pit.

In Orchard 1, all methods predicted the right amount of bitter pit, considering the standard deviation (SD). The Ethephon method was most accurate. In orchard 2 none of the methods predicted the right amount of bitter pit. The method with the closest prediction was Ethephon (37% off). In orchard 3, none of the methods were correct in predicting the amount of bitter pit after 12 weeks in storage. Nevertheless, the Ethephon method was within a prediction range of 33% (see Figure 2).

One aspect of bitter pit prediction that is not considered in any of the current methods involves the amount of fruit left in the orchard due to bitter pit at the time of harvest. The average in-field loss from bitter pit was between 7% and 22%. In both, Orchard 1 and 2, we determined that 7% of fruit was left in the field due to bitter pit. Orchard 3 had more in-field bitter pit with an average of 22% of the crop with discernable bitter pit symptoms before harvest. After 12 weeks in storage, between 25% and 64% of the apples harvested symptom free had developed bitter pit. Orchard 1 developed 25%, Orchard 2 64% and Orchard 3 48% bitter pit in storage. This means that one cannot predict storage bitter pit potential based on field symptom expression alone. For example: we had two orchards with low bitter pit incidence in the field (7%). However, one orchard developed 25% bitter pit in storage, while 64% of fruit from the second orchard developed bitter pit. The orchard with the highest preharvest loss due to bitter pit, was not the worst orchard for bitter pit development in storage.

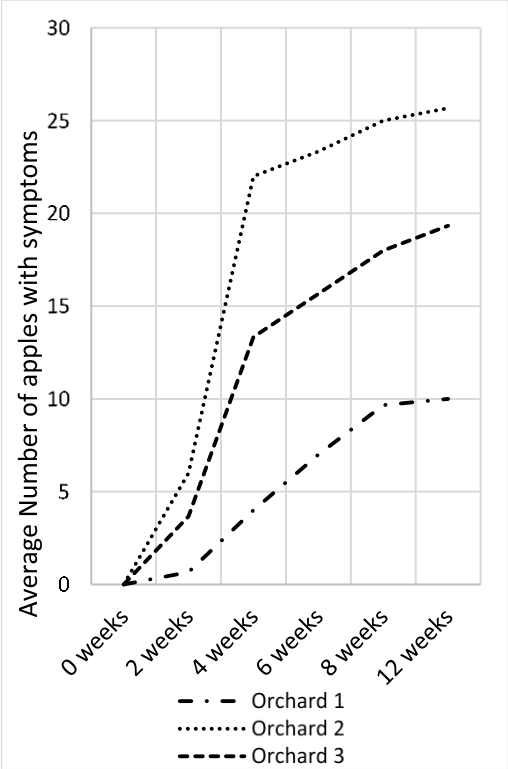

Figure 1: Average amount of untreated control fruit developing bitter pit during 12 weeks of storage (1 week at 50°F followed by 11 weeks at 36°F). n=40

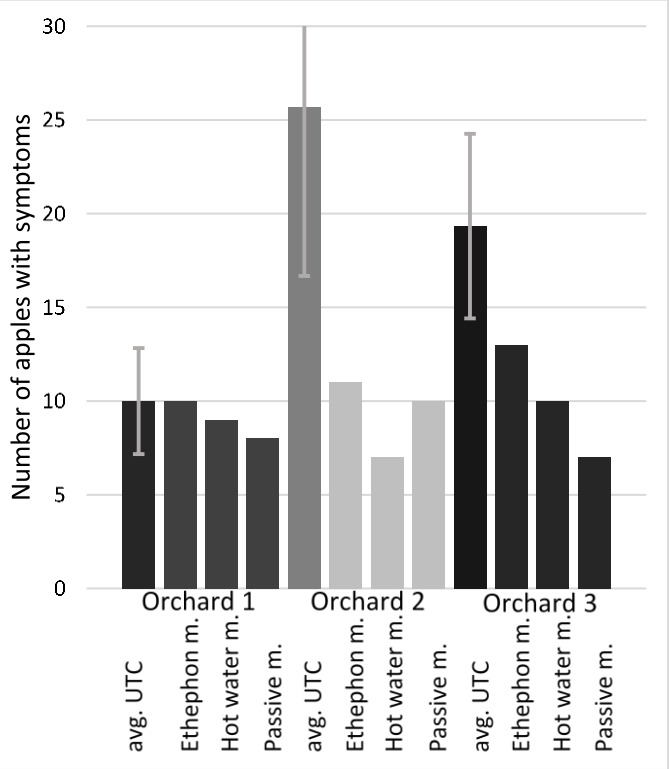

Figure 2: Comparison of three methods to predict bitter pit in Honeycrisp apples, n=40, error bars = ±SD. (UTC = untreated control)

WSU Tree Fruit Extension team

WA 38 starch scale: For the new starch scale, 638 apple samples were cut; 81 in September, 371 in October and 186 in November.

To achieve a surface reflecting the middle of the core, WA38 apple fruit were cut, unlike other industry specific varieties, right through the equator. During the experiment, two predominant patterns were observed. The commonly known "flower" pattern (see Figure 3), which is characterized by 5 "flower petals" growing with advancing maturity. The other pattern was named "radial" (see Figure 4), and can be compared with a "sunrise". It clears larger parts of the cut surface in a radial fashion with advanced maturity. The patterns appeared in a 6:4 ratio.

Another observation was the slow disappearance (aka slow fruit ripening) of dark color and consequently starch. This was like observations from previous years with cv. WA38 apples at the WTFRC. In the new starch scale this fact was considered and a scale with half point increments was developed.

The experiment also showed that the starch patterns took longer to develop, compared to other industry specific varieties. Depending on fruit temperature and maturity, the development of a complete starch staining took up to one hour. In most cases the pattern developed fully after 30 minutes. If the fruit is warm, starch readings are possible in less than 5 minutes.

2018 plans: we will incorporate feedback received from our industry focus group and will ask for additional input from the Apple Horticulture and Postharvest Committee during the January 24, 2018 Research Review. The scale will then be refined in 2018 by incorporating: the exact time and conditions needed for accurate starch readings, a comparison of starch movement on and off the tree, and a vertical starch pattern to predict the likelihood of splits in the stem bowl.

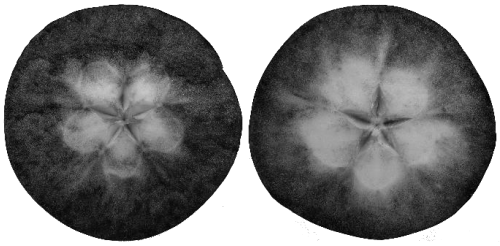

Figure 3: WA38 two different 'flower starch' patterns

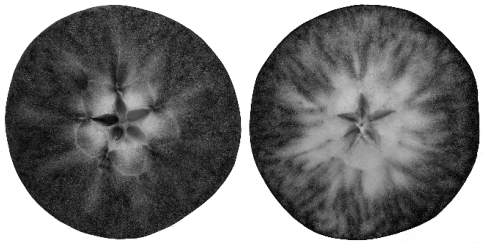

Figure 4: WA38 two different 'radial starch' patterns

Apple Disorder guide:

A total of 7,833 photographs of 106 defects (many with multiple cultivars [158 defect x cultivar "entries"]) were created during 2017. Based on those results, we developed a list of missing items to be collected during harvest and storage in late 2017. Rob Blakey has worked with Darrell Kilgore and Matt Ziegler from the WSU CAHNRS Video & Photography Department to produce the final publications. These will be: (i) an online guide with rotatable photographs with annotations and descriptions, and (ii) a hard copy with photographs and defect description. Depending on resources, a Spanish version could be produced at a later stage.

Currently Blakey and Hanrahan are creating (i) descriptive text for each disorder, (ii) annotated call outs to appear on points of interest on the rotating photographs, (iii) a sorting system including cross linking, common misidentification, and links to additional sources.

The project is being funded internally by CAHNRS Extension Publications with costs to be recovered from selling the hard copy version. It was agreed that any profits would accrue to the Tree Fruit Postharvest Extension Specialist. Karen Lewis has taken over as PI since Blakey left WSU employment.

Postharvest fruit school:

A Postharvest fruit school was developed by the WSU Extension Tree Fruit Team to be held in two locations (Prosser, Wenatchee) March 20-22 of 2018. Fruit Schools are designed to delve deep into topics important to the industry using a combination of presentation, discussion, hands-on activities, and demonstration. Regional, national, and international speakers (12 invited speakers) will be equally located at both Wenatchee and Prosser to facilitate interaction with attendees. To make the meeting affordable, we have secured 13 sponsors to date. The first day will focus on the principles of postharvest science and management. The second day will address crop specific problems with sessions for apples and berries (morning), and cherries and pears (afternoon). The third day will be warehouse tours. Registration has been open since November 2017, and to date we have 66 participants signed up, for a total of 250 available seats. More information and online registration is available under: http://treefruit.wsu.edu/postharvest-fruit-school-2018/

Quality of HC strains and early maturating selection

Our main focus of the experiment was to determine how Premier Honeycrisp performed in storage compared to other common strains of Honeycrisp. The results reported here are preliminary. A full report will be made available upon completion of the experiment. We evaluated all fruit in December and found Premier Honeycrisp to have varying degrees of splitting (0 or 22%), bitter pit (0 or 2%) and soft scald (0 or 7%) when stored in a common cold room (Table 3). Utilizing the Honeycrisp storage protocol reduced the incidence of soft scald from 7% to zero. Premier Honeycrisp displays harvest maturity, storage life, and eating quality after storage similar to other common Honeycrisp strains/selections (not shown).

Table 3: Strain, harvest date and types of cullage for nine batches of Honeycrisp representing commonly used strains. WTFRC 2017.

Honeycrisp	Harvest Date	% Bitterpit	% Softscald	%Splits	% Total Cullage
Premier Box B[Y]	8/28/17	-	-	-	0%
Premier Box A	8/28/17	-	7%	-	7%
Premier	8/30/17	2%	-	22%	24%
Firestorm	9/1/17	57%	-	-	57%
Royal Red	9/7/17	9%	-	-	9%
Standard	9/8/17	35%	-	-	35%
Firestorm A	9/15/17	2%	-	-	2%
Firestorm B	9/15/17	-	18%	1%	19%
Standard	10/13/17	8%	2%	-	10%

Footnote: Y = Samples stored following Honeycrisp protocol; all other samples stored at 33°F.

Collaborative research

We continue to build productive and dynamic research and outreach partnerships with a number of cooperators on projects relevant to pre and postharvest fruit quality management (Table 4).

Table 4. 2017 Hanrahan/WTFRC collaborations on pre-and post- harvest fruit quality projects.

COLLABORATOR(S)	PROJECT	HANRAHAN ROLE
2017 (continuing and new)		
Evans/Auvil	WSU breeding: P3	Collaborator storage evaluation
Univ. of Talca*	Superficial scald control	Contract project
Blakey	NEW WSU Apple Disorder Guide	CO-PI
Willett	Apple rootstock and scion evaluation	collaborator

*project costs completely covered by companies/external projects

In addition, Hanrahan and her team participated in several events geared towards organic production to develop specific knowledge and expertise in this area. Further, since roughly 40% of all apple trees to be planted in 2018 will belong to one of ± 30 clubs, the team visited established plantings, obtained samples to observe and taste and gathered information on horticultural challenges, maturity, storability etc.

Lastly, Dr. Hanrahan went on two trips oversees to Europe (June/July), and Chile (Nov. 11-27). In Europe, Hanrahan attended an ISHS sponsored conference in Poland last summer and spent several additional weeks in Germany to learn about postharvest applications and to connect with research and extension personnel. In Chile, Hanrahan was hosted by Dr. Carolina Torres, Director for International Affairs and Professor in the Pome Fruit Research Center, University of Talca, Chile. We performed experiments to test a novel anti scalding agent developed and patented in the Torres lab. Hanrahan participated as invited speaker: Avances en Technologías en Postcosecha de Pomáceas y Cerezas (International Workshop: Advances in new Technologies for Pomefruit and Cherries) and visited local orchards and packing facilities for cherries, apples, and pears.

The information gathered on those trips is being shared with the WTFRC board and management, local collaborators, the extension team, and industry stakeholder groups (Pomclub, NCWFA) through a variety of means (report, ppts, personal visits). Further, we utilized the information to optimize our information transfer in the upcoming postharvest fruit school.

2017 Outreach Activities

Peer reviewed publications:

R. Karina Gallardo, Ines Hanrahan, Chengyan Yue, Vicki A. McCracken, James Luby, James R. McFerson, Carolyn Ross, and Lilian Carrillo-Rodriguez. 2017. Combining sensory evaluations and experimental auctions to assess consumers' preferences for fresh fruit quality characteristics. Agribusiness: an International Journal (accepted)

Hanrahan, I., Vorholz, M., DeEll, J. 2017. Identification and management of carbon dioxide injury in apples. Acta Hort. (submitted)

Leisso, R. S., Hanrahan, I., Mattheis, J., Rudell, D., 2017. Controlled atmosphere storage, temperature conditioning, and antioxidant treatment alter postharvest 'Honeycrisp' metabolism. HortScience. 52(3):423–431

Mattheis, J., Rudell, D., Hanrahan, I. 2017. Impacts of 1-Methylcyclopropene and controlled atmosphere established during conditioning on development of bitter pit in 'Honeycrisp' apples. Hort.Sci. 52(1): 132-137.

Abstracts/posters:

Hanrahan, I., Vorholz, M., DeEll, J.: Identification and management of carbon dioxide injury in apples (poster at CaMa)

D.A. Neuwald, N. Klein, C. Prunier, S. Gehweiler, L. Hart, C. F. Şerban, I. Hanrahan: Crop load affects the incidence of watercore in 'Fuji' apples (poster at CaMa)

Other publications:

Hanrahan, I. & Perrault M.: Honeycrisp Supermarket Survey Results. Published Aug. 12, 2017 http://treefruit.wsu.edu/news/honeycrisp-supermarket-survey-results/

Hanrahan, I. & Blakey, R.: Honeycrisp storage recommendations revisited. Published Sept. 8, 2017 http://treefruit.wsu.edu/news/honeycrisp-storage-recommendations-revisited/

Musacchi, S., Hanrahan, I., Lewis, K., Evans, K., DuPont, T. WA 38 Characteristics and Horticulture (WA 38 Factsheet); http://treefruit.wsu.edu/wa-38-characteristics-and-horticulture/

Klein, N. & Hanrahan, I. 2017. Ein aufgehender Stern am Apfelhimmel (a rising star in the apple sky)**.** Obstbau/Weinbau (accepted)

Hanrahan, I. & Perrault, M. The variabilities of Honeycrisp: Good to know http://www.goodfruit.com/the-variabilities-of-honeycrisp-good-to-know/

Field days:

Sunburn prevention (presenter)
Cosmic Crisp field day at Sunrise: fruit quality and maturity demonstration (presenter)

Talks:

NY Fruit Growers Association: Current best Honeycrisp Management Practices in Washington State
NCWFA in Wenatchee: How to increase packouts

WSU Extension Yakima open house: apple varieties
Tree Fruit Production Trends in Washington State (Germany: Bavendorf and Esteburg, Chile: Talca)
Pomclub (2 talks): European Travel summary; Hanrahan program overview
Sunburn prevention (Spanish session, WSTFA Annual meeting, presented by Mendoza)

Media coverage:
Learning Cosmic lessons by S. Dininny, Dec. 2017, Good Fruit Grower:
http://www.goodfruit.com/learning-cosmic-lessons/

Other:
IFTA Annual Conference: harvest and postharvest (3-hour session, session manager)
MsSc committee member for Corina Serban (Bitter pit management in Honeycrisp)
Attended CaMa (ISHS) conference in Warsaw followed by Eurfin postharvest group meeting
Fielding fruit quality questions and troubleshooting storage problems (±200 contacts/yr.)
WA 38 to Dan Newhouse (delivered by Kate Woods, NHC) and Jay Inslee
WVC postharvest lab (WTFRC quality lab and storage disorders, 2-hour lesson plan