

NE1018 Postharvest Biology of Fruits
Granlibakken Conference Center, Tahoe City, California
July 13-15, 2007

Friday, July 13 - Meeting convened at 1:15 p.m.

Welcome from Bruce Whitaker, chair. Thanks to Beth Mitcham for meeting arrangements.

Bradley Hillman – new NERA advisor. At Rutgers Univ. as a research director. Plant pathologist by training. Still has a research lab and is an administrator at Rutgers. Is part of several multi-state projects himself. There is more money being funneled into multi-state projects than in the past so it is important to keep the money coming in. Regional projects will continue to be important. Want to show the interdependency of the group in the rewrite. Not just a coordinating committee (another category of group). Earmarked money was eliminated for the past year at the federal level. Some states gained by this and some lost. Earmarks are coming back this year it appears; about half as many as previously. These are not yet identified. Willing to help with the rewrite process and NE1018 group can email him. Experiment station directors want more regional projects so it is easier to spread the money around. Coordinating committees can also get money. Why are they encouraging people to change to a coordinating committee? Differences between a coordinating committee and a multi-state project are not clearly defined. Interdependency is one difference. Does not see that it is advantageous to go to a coordinating committee, although it is administratively easier and involves less paperwork.

Bruce Whitaker says that we must have the project rewrite request (justification) submitted by Aug. 24, 2007. Another deadline is in March for a draft of the rewrite. The request to rewrite can be short, 1 page. Must make it such that it shows interdependence.

Introductions:

Jennifer DeEll, Ontario Canada; Chris Walsh, Maryland; Beth Mitcham, California; Penny Perkins-Veazie, USDA Oklahoma; John Labavitch, California; Herb Aldwinckle, New York (Cornell-Geneva); Cindy Tong, Minnesota; Henrik Stotz, Oregon; David Rudell, USDA Washington; Aya Akagi, Oregon (grad student - H. Stotz); Jim Mattheis, USDA Washington; Renae Moran, Maine; Gene Kupferman, Washington; Bob Prange, Nova Scotia, Canada; Bruce Whitaker, USDA Maryland; Chris Watkins, New York (Cornell-Ithaca); Craig Kahlke, New York, Cornell (Extension). Late arrivals: Randy Beaudry, Michigan; Dan MacLean, California (research assoc. - B. Mitcham); Nobuko Sugimoto, Michigan (grad student - R. Beaudry); Dennis Murr, Ontario, Canada (Univ. of Guelph).

Objective 1 – To evaluate postharvest requirements of new and existing varieties

Renae Moran (ME) - Discussion Leader

Honeycrisp apple

This popular new cultivar continues to be widely planted across the U.S., with first harvests in new locations (outside Minnesota) starting to be evaluated.

Renae Moran (ME) presented data on soft scald problems with Honeycrisp and a discussion of Honeycrisp apple was entered by all. Honeycrisp currently sell quickly in Maine but will be stored in the future, which will increase chances of developing soft scald. Delayed cooling helps to reduce soft scald but can increase bitter pit in some years. No CA storage is being used in ME for Honeycrisp; if held at 3 °C for 3 months fruit lack flavor. Not sure what to tell Maine

industry at this point, as the response varies year to year. There seems to be variation from orchard to orchard. Members from several other locations agree with this observation.

Cindy Tong (MN) says she has heard that Honeycrisp does well on poor soils, so she wonders if fertilization is linked with storage problems. Renae Moran says she does not think so (Maine has poor, rocky soils where apples are grown). Bob Prange (NS) says that crop load will have an effect on soft scald in Honeycrisp and has pictures in his report showing that it makes a big difference in this apple. Less crop load yields redder color, higher firmness, and more sugar. On a good site you can push the load up. Ontario sees variability tree-to-tree and limb-to-limb (Jennifer DeEll). There are also fruit shape differences from limb to limb or on same branch. Color will also vary. Cindy Tong says Honeycrisp is genetically very plastic.

Jennifer DeEll has not analyzed data on Honeycrisp yet, but states that delay in cooling does not help with soft scald in Ontario and will increase bitter pit. Bob Prange says that moldy apple taste is transferred from decayed to good apples in bins of Honeycrisp. Stem punctures also are a problem. In some orchards, the stem is clipped at harvest to prevent punctures and decay later. Dipping fruit in tanks introduces pathogens. Industry in Nova Scotia told to stop dipping and it has reduced decay. Bob Prange says they continue to recommend CA storage of Honeycrisp (works well in Nova Scotia). Other locations state that CA storage is a problem with Honeycrisp. No bitter pit problems in Nova Scotia. Prange et al. have used MRI to detect the soggy breakdown in Honeycrisp (pictures in the NS report). Gene Kupferman (WA) says that an acoustical tester will help sort out fruit with water core and internal browning. It is a commercially available unit that might be able to help with this problem. Honeycrisp exhibits splotchy browning, which is hard to detect. Bob Prange comments that orchards with aggressive management often have worse problems than lightly managed orchards. He suggests that neural network analysis, data mining that looks for connections among data sets, might be useful in determining detrimental and beneficial practices. Cindy Tong suggests that NE1018 might look at management in orchards in different locations to see what role it plays in development of disorders. Bob Prange says that use of the neural network software could make it possible to collect all required data from existing orchards. Gene Kupferman expresses interest and willingness to work with commercial producers to fill out forms if someone comes up with the criteria. The data probably already exist; might need to do a preliminary assessment. Cindy Tong says they have seen internal breakdown in MN when there was an early freeze during the very small fruitlet stage. Bob Prange feels that cumulative stress may be a key factor in subsequent disorder development. Point made that it might be best as a preliminary approach to use the data from orchards where management practices and environmental factors are already documented. It might even be worthwhile to include fruit position on the tree as a factor. Cindy Tong responds that harvesting from north, south, east and west parts of the tree did not matter. It may be more the top to bottom of the tree that is an issue. Chris Walsh (MD) said that there was an English study on climate in the orchard that showed top to bottom effects. He finds it interesting that a cool-tolerant apple has so narrow a temperature range and seems to have low temperature related problems. Bob Prange thinks that stressing of the apples at the treetop may be the problem. Chris Walsh says that blooming on spur and laterals may give you two different age apples and that could have an effect on what is in the bin. Gene Kupferman agrees that fruit is different on laterals and spurs. Most trees on M26, some on M9 rootstock. Gene says that in Washington state, Honeycrisp have been planted in cool and warm areas and many are on M9 rootstock. He anticipates storage problems in a few years when the first crops are harvested. Penny Perkins-Veazie (USDA-OK) asks why Honeycrisp is so popular when it has so many problems. Honeycrisp is very profitable because consumers like the taste and texture (they stay very crisp). A curious fact is that many problems are specific to certain areas of the country/world. Warmer regions seem to have fewer disorders than colder places (but MN & NS are exceptions). Cindy

Tong asks what data to collect in the field. It was decided that a breakout group should discuss this and it should be put into the project rewrite. Jim Mattheis (USDA-WA) makes the point that there are no standards for Honeycrisp in different growing areas, so there is a lot of variability in the market.

Browning of apples

J. DeEll (ON) - Evaluating the browning potential of new apple varieties for the fresh cut market. Looking for different options; summary in report. British Columbia (BC) and Ontario had variability in browning between the two locations. Looked at Nature Seal and 1-MCP effects, and also investigated treatments to reduce decay of fresh cut apples. Peter Toivonen (BC) is working on this. Processor wants a year around supply of Empire fruit and ON has tested different combined treatments and storage protocols to make them last longer. BC working on this with Ambrosia. This is a very promising apple for them and they want to extend its storage life, but there is a need to establish optimal conditions for this apple because there have been problems in the past. It is susceptible to soft scald and is chilling sensitive with an internal browning problem (much like Honeycrisp). The biggest thing that stands out is the difference between ON and BC fruit.

Herb Aldwinckle (NY-Geneva) asks about gene silencing of PPO browning enzyme in apples and what people think of it. Gene silencing is considered 'clean' molecular biology because there is no cross-species involved in the GMO. There are some new apple lines available with PPO silencing constructs. Gene Kupferman responds that there was an industry discussion on the GMO apple that does not brown, and they are not sure how to deal with it. Beth Mitcham (CA) asks about disease problems in this variety. Do not see any difference so far. No gene from another organism involved. Herb Aldwinckle says that some of the PPO genes are silenced but not sure of the exact technology or whether all of them are down-regulated. Got few negative reactions from brokers in Washington. Chris Watkins (NY-Ithaca) says that the response to silencing genes was positive in a meeting he recently attended. Also makes the comment that browning is a sign that something is wrong and if it does not occur (i.e., food safety type indicator), we may have a real challenge on our hands. Jim Mattheis says that there will be problems in Washington state because of the required physical separation in the orchard from organically maintained trees.

Morning break

Beth Mitcham announces that a registration fee of \$45 will be collected to cover meeting costs, and goes over housekeeping details for meals, etc.

Resume Objective 1

Randy Beaudry (MI) - Quantified ester production by fruit representing the Core Collection of the USDA apple germplasm repository. Ester matrix was put together. Shows the abundance of each type of compound. Determined as the average of all the apples from a given accession. The larger the fruit the higher the GC/MS response for esters. Fruit under 10 g have a different ester profile than larger apples. Hypothesis that it relates to seed dispersal, smaller fruit attracting different animals than larger fruit. Pathways seem to be regulated rather independently. Most of ester production is in the fruit skin. Bruce Whitaker (USDA-MD) comments that this is counter intuitive with respect to the low ester production by small apples. Randy says that they are different metabolically. This study was done on whole fruit. GRIN system is for documenting phenotype for each line of apple. It is a huge data system and you can search for certain attributes. Dave Rudell (USDA-WA) asks if they looked at parental distribution, but Randy says

so far they have not. Whole idea was to look at clustering of compounds and what was regulated together. Bob Prange asks about correlation to scab resistance and Randy says you can look at this database and get information. Scab resistant apples often taste bad. The study also classed all the fruit on the basis of taste. Some lines are very astringent. Chris Watkins asked how much of this is influenced by harvest date. Nobuko Sugimoto (MI) answered that there was a harvest code indicating when to pick and that is what she used. The stage of development and ripening on a given date varies each year so it took some work to harvest at the proper maturity. Bob Prange asks about crop load and Randy said that it varied widely. They will not do this study again at this magnitude. Herb Aldwinckle says there seems to be a negative correlation between fruit size and esters. Jim asks if fruit size is part of the GRIN database and the answer is yes. Nobuko comments that all the fruit in this study were weighed.

Discussion ensued about classification of most lines as *Malus domestica* or *pumila*. *Domestica* is still more common. Herb Aldwinckle says there is a new book out about apple lineage and taxonomy.

Objective 2. To develop sustainable controls for physiological disorders, diseases and pests
Henrik Stotz (OR) - Discussion Leader

Beth Mitcham (CA) - Report on research by visiting Israeli scientist Edna Pesis during a sabbatical in Beth's lab at UC-Davis. Quality and storage life of Granny Smith apples as influenced by several treatments including initial ultra-low oxygen, holding at room temperature, high CO₂, 1-MCP, and DPA, followed by storage in air or CA. Some of the data are presented under Objective 5. Summary of work in the report (complex). Low oxygen, DPA and 1-MCP controlled scald. Bitter pit incidence was reduced by treatments with ultra-low oxygen. Low oxygen might be a good treatment for organic fruit. 1-MCP treated fruit had bigger bitter pit spots, but Chris Watkins questions if it is really bitter pit. Beth said that it did look like bitter pit, but she did not know about the timing. The controls did have bitter pit. Jim says that they have seen the same bitter pit effect with 1-MCP treated fruit with bigger spots compared with untreated controls, but there was not a difference in the incidence. Chris Watkins asks why 1-MCP would have an effect on bitter pit. Early Ethephon treatment can reduce bitter pit. Henrik Stotz (OR) says ethylene will induce production of calcium binding proteins like calmodulin. Bob asks if the movement calcium is affected. Location of the calcium in fruit tissues might be the real issue. Suggested that 1-MCP could be used in a test system for bitter pit susceptibility. Bob Prange says that low oxygen can give an off flavor rather than improve it. Beth responded that they did not taste the fruit until 4 months after the initial ultra-low O₂, which probably allowed for recovery from any off-flavor development.

(CA report - continued) Silicone based surfactants tested for disinfestation of surface insects on sweet cherries. Chemicals were effective in removal of insects but are not registered for this use. Cherries are treated with methyl bromide currently and alternatives are being sought. Gene Kupferman asked about fruit quality because too much Silwet will cause damage. Others surfactants did not cause any damage at the highest concentration. Also looking at table grapes and disinfestation with ethyl formate. Trying to refine protocols for this industry. Want to lower temperature requirements for treatments to avoid fruit injury. A more formal project for citrus industry on use of ethyl formate to control thrips in navel oranges. Are putting in a proposal to pursue the citrus work in more detail.

Chris Watkins (NY-Ithaca) for David Rosenberger (NY-Geneva) - Levels of *Penicillium expansum* spores the orchard as a source of postharvest inoculum. Data supports results of last year showing that contamination on harvest bins rather than on the fruit or in orchard soil is the greatest source of spores. Preharvest sprays with Captan effective at reducing postharvest decay by *P. expansum*. Gene Kupferman warns that Captan is a problem postharvest from time to time as it can cause injury. He would urge serious caution with it. Pears also have shown injury preharvest. Dave Rosenberger noted that apples treated preharvest with Pristine had a higher incidence of CO₂ injury after CA storage than fruit receiving other treatments.

Herb Aldwinckle (NY-Geneva) for Geza Hrazdina (NY-Geneva) - Well-established ACC synthase antisense-suppressed transgenic lines of Gala and McIntosh apple. Currently evaluating McIntosh lines for reduced climacteric ethylene production and extended storage life.

Jim Mattheis & Dave Rudell (USDA-WA) - Evaluating low oxygen treatments in pears. Bartlett develops senescent scald. Also worked on Anjou. In Bartlett found less internal breakdown. Some speckling observed but low oxygen effect was not consistent. There is still much interest in controlling scald by low oxygen since 1-MCP inhibits ripening. Speckling is going to be an issue and will work more on this. Incidence of speckling increased with the duration in low oxygen storage. Gene Kupferman comments that the orchard environment is most likely responsible for variable postharvest results. Orchard to orchard variation is always a problem and he wants to know how we should be dealing with this. Jim Mattheis replies that we need to make risk management decisions about some of these treatments. Bob Prange says it may work best to shock with ultra low oxygen and then bring oxygen back up to a non-injurious level. Beth Mitcham asks how much CO₂ was present; 0.5% is Jim's answer. Chris Watkins recalls that Dave Blanpied had a checklist of conditions that had to be met in order to use low oxygen effectively. There were differences among regions of the country. Gene Kupferman adds that Max Patterson gave him a thesis on a study of apples born on spurs through one-year-old wood. Skin of Bartlett fruit was unblemished and they ripened normally. Henrik Stotz asks if this is specific to winter pears and Jim says that it has only been reported for Anjou. Is there a difference among locations for scald incidence in Anjou pears? Bruce Whitaker states that there is clear evidence for this, and Gene Kupferman adds that in a study he did comparing Anjou fruit from Hood River, OR and Wenatchee, WA scald susceptibility was very different.

Gene Kupferman (WA) - Work on Anjou pear and superficial scald. There are problems with buyers wanting different types of packs, which requires repacking fruit. Want to store in bins longer periods of time. Tried to develop a risk management system for scald in pears based on weather. Big differences in how the orchards face in Hood River, OR vs. Wenatchee, WA. When they tried to use Hood River-based predictions in Wenatchee, it did not work. Orchards in WA face all different directions and are in canyons, so the temperature planning for them is not working as well. Chris Watkins comments that moderated temperatures do not work well in scald prediction models. Air temperature readings were used in the study. Wenatchee fruit require more time in storage to develop scald levels comparable to those in Hood River fruit. Gene wants to model scald and would like cooperators. Some of the pears will not ripen properly in the home after purchase and this is a problem. Can pear fruit be drenched with an antioxidant? Ethoxyquin will cause chemical burn but Hood River had a different experience. If fruit are washed later after treatment then injury is prevented. Thermofogging is discussed under Objective 5; this is a new suggestion from Europe. It tends to unevenly distribute the antioxidant and fruit on top in the bins are more prone to injury. This is a residue problem as well as a treatment effectiveness issue. Industry is still interested in thermofogging. Less phytotoxicity and

more even distribution are the goals. Ethoxyquin is an option but will then have to pack the fruit. This really has to be done in big rooms because results could differ from those in small tests. Beth comments that she thought ethoxyquin was a standard treatment, but it is not. There are several different ways the packers are dealing with it. Would 6% burn be more economical than to keep repacking?

(WA report continued - lenticel breakdown) - Occurs after packing process and is primarily seen in Gala apples. It does occur in other long-term storage varieties. Does 1-MCP make it worse? Looked at maturity after the packing line test. More mature fruit tends to have more severe symptoms. Results differed by orchard. Will have to do statistical analysis to see if this is significant. Lenticel breakdown (LB) is a new problem that has occurred since use of 1-MCP began. Treatment with 1-MCP enabled longer storage of Gala fruit, which may explain the correlation. Some years are much worse than others. Some warehouses believe that 1-MCP is responsible, but this was not supported by the data. They now have the need to market Gala over a long period of time and there is a large volume of them. So it appears that the longer storage period is really the issue. This year was a very low year for LB. Is it because packers now know how to handle the fruit properly, or was it just a low incidence year? Agrofresh is going to provide packers with a blue dye that is supposed to indicate the risk of LB on the basis of greater dye uptake by fruit with more open lenticels. Soap stress is another predictive method. Study conducted to find if these methods work. The soap and dye tests gave different results. The dye test does not seem to relate to the packing line test, so the soap test may replace the dye test. Also investigated the role of surfactants in LB. As concentration of the surfactant increases there is more lenticel breakdown. Take the soaps and wax out of the line and there may not be as much of a problem with LB. Role of iron sulfate in packing line and calcium chloride on lenticel breakdown. Beth Mitcham points out these chemicals are also used in the orchard. Iron tends to make it worse, but it was not a large effect. The role of fruit peel mineral content on LB. Eric Curry (USDA-WA) previously found correlations between LB severity and fruit mineral content. Compared fruit that had lenticel breakdown vs. fruit that did not and there was no difference in fruit from any orchard. Bob Prange asked about packing material. Fiber trays are used. No poly liner in a fiberboard carton. Gene says it does not matter how the fruit are positioned. Bob's point is that lenticel damage might be less if there was less restriction of venting away volatiles. He thinks that very low levels of organic volatiles could cause LB. Corrugated packing materials could also be a source of injurious compounds. There are many volatiles released by cardboard and Randy Beaudry has determined this by GC/MS. Randy has also seen damage from inks. Gene is interested in other ideas if anyone has them. Gene says that the longer the fruit are in water the more danger of LB. Chris Walsh says that he uses dye to predict cracking and he thinks if they take it up it is a maturity issue. He submerses the fruit in water for 24 hours (not allowed to float). Post storage dye studies correlate better than at harvest studies.

Bob Prange (NS) - Fungal bio-fumigant. Produces a combination of volatile compounds. Very active at warmer temperatures but not very good below 5 °C. Very effective at controlling postharvest fungal diseases and bacteria including *E. coli* and *Listeria*. Also controls apple replant disease. There is new management in the company that developed this technology and they are not interested in pursuing postharvest regulatory approval. John Labavitch comments that he knows of studies where they got variable results using this. Production of volatiles by the fungus was shown to vary and this may account for the differences in efficacy observed. Their group has published the fungal volatile profile. NS is also developing method using chlorophyll fluorescence to determine thresholds for low oxygen tolerance in use of CA to control apple scald. Results are promising and this technology could be a help in the organic market. It is

currently used in Europe. Beth Mitcham asks about the ethanol detection system that was being developed but it does not appear to have been commercialized.

Meeting adjourned 5:50 p.m.

Saturday, July 14 - Meeting reconvened at 8:30 a.m.

Objective 3 – To develop recommendations for the beneficial use of essentially safe postharvest chemicals, such as 1-MCP, on fruit to assure high quality and wholesomeness.

Jennifer DeEll (ON) - Discussion Leader

Announcement by Gene Kupferman that there are disorder/disease identification cards available from the Good Fruit Grower.

Randy Beaudry (MI) - Measured sorption of 1-MCP by bin wood over time. Damp wooden bin absorbs 1-MCP much more than just the fruit alone. Tried to mimic the volume ratio of fruit to wood in typical cold storage rooms. Also tested commercial CA storages and found that 1-MCP fell from 1000 ppb to 10 ppb over 24 hours. If wooden bins are used, more 1-MCP is required to be effective, about 1000 ppb. Red Delicious apples had a lower shift in the dose response curve and were affected less than Jonagold. Plastic bins do not absorb 1-MCP, so less can be used. Wet oak absorbs 1-MCP much more than dry oak, and new oak absorbs less than old. This does not seem to be related to surface area. Cultivar difference may be due to skin permeability. Jim Mattheis comments that 1 ppm 1-MCP can only be introduced in apple room once, it is not permissible to supplement to maintain a level of 1 ppm. It appears that 1-MCP does not desorb from the wood after it is bound. Bob Prange asks how much 1-MCP it would take to saturate the wood. Beth Mitcham interjects that there is less sorption of SO₂ during fumigation after the boxes have been exposed once. Bob Prange says that ozone is the same, less is taken up by the bins with each successive treatment. Randy replies that he does not know what the limit, but this was not studied. Bruce Whitaker comments that if 1-MCP desorbs at all, it probably occurs later when the boxes are out in the air and heat.

MI continued – Also did some work on 1-MCP treatment of bananas. Found that 3 ppb is enough to fully treat banana fruit. Cardboard in the room competes with the fruit so a little higher dose of 1-MCP is needed. HD polyethylene liners kept the fruit green. Delay of ripening was very dose dependent. The cardboard or the moisture content of the cardboard may partially account for variability of the response. Beth Mitcham says grape boxes are lightly coated with something that might help in this situation (reduce moisture uptake and sorption of 1-MCP). Penny Perkins-Veazie asks about recycling treated boxes. Gene Kupferman comments that there was a move to plastic bins until the cost of plastic went up. Packers are now looking at some other products. If a liner used, is it better to put it on the inside of the box or the outside of the box? Gene says this is an issue in pear industry. Beth states it depends on what your intent is, keeping moisture in the fruit or keeping the box dry.

Beth Mitcham (CA) - Field applications of 1-MCP in pears. Increased concentration over year before because it was not enough and dosage may still not be high enough. Regulations insist that the concentration must be calculated on a per acre basis, but the trees are huge so the dose per tree is reduced. Got about 1 lb greater firmness in treated versus control fruit. Very subtle effect of 1-MCP when applied in the orchard is in contrast with effect of postharvest application, which can over inhibit pear ripening. Will try several higher concentrations and different

maturity levels this season. It may turn out that pre-harvest 1-MCP will not work on pears. Cindy Tong asks how the field application is done and how different concentrations are determined. Beth replies that an oil in the solution slows release of 1-MCP from the cyclodextrin “enclosure” and holds it on the fruit for some time. There is a very strict protocol for application. Chris Watkins says that just getting the treatment on the leaves is good enough. Probably only a small amount of the 1-MCP applied gets to the fruit. Applying liquid 1-MCP to fruit on and off the tree to compare the response and determine if fruit on the tree have more binding sites. CA-Davis also did a study on postharvest application on pears and the temperature was varied to put it on softer, more mature fruit. Similar to some work that Jim Mattheis (USDA-WA) did. Did not find a strong effect of the holding period on ripening. With the fruit that were treated when softer, they did ripen to eating firmness. While it may work in small controlled studies, it may not be practical for the industry. If the field treatment can be made effective, then postharvest treatment will likely be unnecessary in pears. Jim Mattheis says in his study he had one more temperature step, which added more time. Beth says that she also has gene expression data to go with this study. Jim agrees that the laboratory-controlled regimes will work but they are too difficult for industry to do. Chris Watkins comments that with the low concentrations used on pears, the issues related to packing, sorption, etc. become even more critical. Randy Beaudry adds that there is at least 100-fold more 1-MCP used in the field than postharvest and Chris and others think it could even be more. Beth says that ReTain may compete with 1-MCP, but others reply that ReTain is not consistently effective on apples. However, ReTain is registered for use on organic fruit. ReTain will work on pears but the cost was too great for the California industry to use it. Registration for use on pears was also not consistent with what the growers needed to use. Postharvest ReTain delays ripening and it seems to wear off faster than 1-MCP, plus you can treat with ethylene and overcome it. Jim Mattheis says that there are processors who want to use these products because they have more leeway in scheduling. Randy Beaudry asks if Agrofresh will control application of 1-MCP in the field. They want to, but might have to allow certified people to use it. No one is sure how it will work. Gene Kupferman returns to question of whether spraying 1-MCP on the leaves will be effective. Beth believes they did not get enough on the pears because some ripened more rapidly on one portion of the fruit. In apples 1-MCP appears to move through the fruit, but perhaps not in pears. Beth thinks coverage is a definite issue in pears. Agrofresh conducted the applications in the recent studies. Blotchy ripening in pears could be due to the carriers in the formulation. The oil alone may have some effects. California report also included data on 1-MCP treatment of bananas that Adel Kader submitted. Adel is officially retired now but he will still be active in research for a while.

Jennifer DeEll (ON) - Also has pear storage data for fruit sprayed preharvest with 1-MCP. Effects were more noticeable in late harvested fruit. It appears it might be beneficial on pears grown in Ontario. Growers seem interested in the preharvest spray option. Jim Mattheis states that results of the trials in Washington were more like those in the California study with respect to increased firmness of treated fruit. Firmness increase was greater in Ontario fruit. Jim comments that an early harvest is best to allow packing before the pears are too soft. Jennifer used a higher concentration of sprayable 1-MCP.

Renee Moran (ME) – Tested preharvest 1-MCP sprays on Cortland apples to reduce storage scald. There was some benefit but scald was not eliminated. Maine still uses primarily DPA for scald control. Also tested CPPU but not sure that it is useful to growers. Investigated timing of ReTain application but found no difference in efficacy. Chris Watkins says that hot weather in NY influences how well ReTain works. Bob Prange adds that there is no guarantee in Nova

Scotia that ReTain treatment will have postharvest benefits. If the aim is drop control, data from timing of application studies are available.

Chris Watkins (NY) – Examined influence of 1-MCP on incidence of CO₂ injury in susceptible varieties of apple. DPA used to control scald will also prevent CO₂ injury. Growers want to know if DPA treatment should come before 1-MCP. Found that 1-MCP made the CO₂ injury worse if there was a delay in DPA treatment. Low levels of CO₂ are recommended for storage of fruit not treated with DPA. Treatment prior to proper cooling can result in increased injury. DPA is the easy solution to CO₂ injury if it is permissible. Agrofresh is very cryptic about use of DPA. The timing issue is important. DPA must be applied promptly and the first two of weeks of storage are critical for acclimation of the fruit. Beth makes the point that the fruit change substantially during this time. It appears that 1-MCP prevents the acclimation required to prevent CO₂ injury. Not known if 1-MCP will have the same effect when applied preharvest rather than postharvest. Studied delay of treatment with DPA in Rome apples. It is critical to treat within a day or so if 1-MCP will also be used. A 3-day delay in DPA application in Cortland is enough to get an increase in scald in 1-MCP-treated fruit. Gene Kupferman asks what the relationship is between DPA treatment and temperature. If treated too soon after harvest the fruit are not completely cool. Chris Watkins says DPA can be applied on cold apples. 1-MCP prevents scald through inhibition of alpha-farnesene production, whereas DPA inhibits its oxidation. Study of internal browning in Macintosh and Empire apples: Empire held at 32-33 F will develop internal flesh browning due to chilling injury, so recommendation is 35-36 F. Above this temperature internal breakdown becomes a problem. Some people think that 1-MCP makes their browning problems worse, and there is some evidence of this. At 39 F there is a large increase in browning in 1-MCP treated fruit. Increasing storage temperature to avoid chilling injury is causing injury due to 1-MCP. Still studying this phenomenon and currently not sure what is happening. Oxygen concentration could also be involved in this. At the moment there are no clear guidelines for the industry. NY Empire fruit have traditionally not fared well in low oxygen CA. This is why Dave Blanpied worked on low ethylene storage. Bob Prange comments that with oxygen levels reduced to the lowest optimal level, the CO₂ level is less critical. Chris Watkins says that 1-MCP has changed the landscape for Empire apples and the parameters must be determined. Will have more data next year.

NY- (Dave Rosenberger) - Recent work on fungicides presented in the annual report.

Jennifer DeEll (ON) - Efficacy of 1-MCP on stone fruits, plum, peach, and nectarine. Treated plum consistently had higher soluble solids, which is unusual (postharvest 1-MCP treatment). Redhaven peaches showed no benefit. Nectarines responded well, with increased firmness and delayed ripening. 1-MCP did reduce chilling injury in peach. Jim Mattheis states that in WA studies 1-MCP efficacy on stone fruits was inconsistent from year to year. A broad range of responses observed in plums. The ethylene response system in peaches seems to operate differently compared with apples. Dennis Murr comments that in stone fruits there is a very narrow window for effective treatment and if this is missed there is no benefit. Chris Watkins says there is a group in Italy that has compared ethylene responses and signaling in apples and peaches. There is added complexity in peaches, but the mechanisms are not clear. ON also studied effects of 1-MCP on cherry tomatoes and tomatoes-on-the-vine (TOV), and found that treatments were very beneficial. Maintained sepal freshness. For TOV harvest is based on maturity of the end tomato to ensure it is not too green. Industry is excited about the potential of 1-MCP. Stems of treated clusters senesced more slowly and abscission of the fruit was prevented. 1-MCP is registered for use on tomatoes in Canada. Penny Perkins-Veazie

comments that maintenance of vine health results in better tomato flavor. John Labavitch (CA) asks if the fruit have higher starch or sugar content because they are left on the vine.

Jim Mattheis (USDA-WA) - Found that Anjou pears will eventually ripen after 1-MCP treatment at harvest (300 ppb). This is different from the Hood River, OR experience. Bruce Whitaker stated that Hood River fruit used in a collaborative study with Jinhe Bai never ripened. Jim replied that the Wenatchee, WA experiment was done on more of a commercial scale and it took longer to load the room, cool it etc. They found that less stringent CA will allow more rapid escape from ripening inhibition, but long storage duration is still required. Loss of green color proceeds faster than internal softening in 1-MCP-treated Anjou fruit. Buyers do not want to purchase yellow Anjou pears. What amount of ethylene or CO₂ could potentially impact ripening inhibition by 1-MCP? If ethylene is present (1000 ppm) during 1-MCP treatment it will negate the 1-MCP effects. High CO₂ could also influence the effect of 1-MCP treatment.

USDA-WA also conducted a Harvista (pre-harvest) 1-MCP experiment on Braeburn apples and have used it as a model for internal browning. 1-MCP may retard acclimation to cold storage conditions and development of resistance to stress. Harvista worked well for retaining fruit quality in air storage, but browning disorders arise later if the fruit go directly into the cold. With postharvest 1-MCP treatment, a 10-day delay in cooling after harvest will prevent internal browning. WA uses 39 F commercially but no 1-MCP because the company will not sell it to them. If properly handled to avoid browning issues, CA is not necessary for 1-MCP treated fruit.

Objective 4 - To expand knowledge of the influence of cultivar, production practices, and postharvest handling on the nutritional and eating quality of fruit.

Penny Perkins-Veazie (USDA-OK) - Discussion Leader

Sylvia Blankenship (NC) - Informed group about the NC Research Campus at Kannapolis established by Dole and David Murdock. Will be a new research center focused on the nutritional quality and benefits to human health of fruits and vegetables.

Discussion of nutritional quality and the role of fruits and vegetables in the diet. Different countries have various levels of produce quality. Gene Kupferman says Tesco, a grocery from England, will open stores in the U.S.

Beth Mitcham (CA) - Compared optimal harvest maturity, sensory quality, storability among Gala strains with the most red color. Growers are picking fruit at a more advanced maturity than they should. Most showed substantial starch clearing by the time they started to harvest. Looked for difference in harvest maturity in different strains but found very little. Attempt to achieve more red color results in maturity and storage issues. Overhead irrigation might help but may induce more cracking.

Also studied new pear varieties for California. Most of the market is currently Bartlett. Assessment of consumer acceptance. Uniform ripening is hard to achieve and fruit must be picked at proper maturity for meaningful comparison. Work needs to be done on the best ripening regime. A variety called Cinnamon was popular. Gene Kupferman comments it is hard to get Taylor's Gold to russet in Washington. Beth says the same is true in California.

Randy Beaudry (MI) - Developed new Bioyield tester for non-destructive firmness measurement. Can be used to follow decreasing firmness in the same fruit over time. Instrument leaves a very small dimple on the fruit surface without rupturing the tissue. It will damage the first few cell layers. Was more consistent than conventional Magness-Taylor firmness tester. Less variation noted from sample date to sample date. Fruit skin does not influence instrument readings. Beth

Mitcham says that Jim Thompson is doing some work like this. A simple durometer works well. Pretty accurate and non-destructive. Need to get the right size tip and range of force. Modified atmosphere packaging update included in report. Created an Excel user interface to help with decision making for MAP. It predicts what will happen to the oxygen level in a package and what will happen in the case of temperature abuse. It also specifies the packaging needs (way cool!). Inputs are based on data from USDA Handbook 66. What is status of Handbook 66? It is fully accessible on the web and Beth said they got permission to make CD's from the web PDFs. Ken Gross was working on this but he retired in February.

Cindy Tong (MN) - Evaluation of "crispness" in strains of Honeycrisp apple. No agreed upon definition of crispness. Used the "snap" test and assessed fruit of different genotypes. Some stay crisper than others after storage. Some have the Golden Delicious allele and soften, whereas others have the Granny Smith allele and do not soften.

Chris Watkins (NY) - Studied nutritional value of strawberries. Acquired both physical and nutritional data. Evaluated at two maturity stages and stored two different ways. White tip stage strawberries have higher levels of some beneficial compounds than the red ripe berries. An extract of strawberries inhibited growth of cancer cells in culture.

Penny Perkins-Veazie (USDA-OK) - Watermelon is the state vegetable in OK. Watermelon pomace was fed to rats and it improved the health of diabetic fatty rats (they actually lost weight). Grafting can enhance lycopene content in watermelon. Mango varieties have a wide variation in Vitamin C and beta carotene content. Also varied depending on country of origin. Will conduct feeding studies with diabetic mice to see if mango is beneficial. Hot water dip (53 C) is the accepted quarantine method for mango, but this can cause pitting on the skin. Industry and the mango board are looking for a new, better method. Variety differences were greater than differences among countries for the same variety. Poor eating quality of some lots of fruit is probably due to picking too early. Beth Mitcham says there is a recently published book on berry fruit and nutrition in relation to human health, "Berry Fruit Value Added Products for Health Promotion", CRC press.

Objective 5. To expand fundamental knowledge of fruit biology required for development of improved and new technologies for maintenance and enhancement of fruit quality.

John Labavitch (CA) - Discussion Leader

Beth Mitcham (CA) - A German researcher proposed that calcium is not the main factor in bitter pit and blossom end rot in tomatoes, and this idea is being investigated. Gibberellins may play a role. Not the total amount of calcium in fruit that is critical but rather where it is located. Have tried treating tomatoes with GAs 4 & 7, apogee, and ABA. GA increased blossom end rot, while ABA reduced it. GA can influence the development of xylem, and functional xylem is required for calcium transport. Going to try some COX inhibitors. Fruit from ABA-treated tomato plants are very large compared with those from control plants, while the roots are very small. Applied treatments on the week after flowering and then every week thereafter. Apples do not tolerate these treatments as well as the tomatoes. Encouraged by the tomato work. Bob Prange asks if you get more water loss with GA and Beth says this may be the case. Less water loss and less transpiration after ABA treatments may explain the large fruit. Question raised about occurrence of watercore and bitter pit in the same fruit. Randy Beaudry answers that it does happen.

Dan MacLean (CA) - Scald in Anjou pears. The red side with less chlorophyll is scald free and the darker green side develops scald. Pigment pattern suggests that the phenylpropanoid pathway is somehow involved. Stored fruit for 5-6 months. Took tissue from each side of the fruit and studied gene expression. On scalded side genes of the flavonoid pathway had greater expression. There was some work by Cindy Barden and Bill Bramlage that looked into the pigmented, sun side having less scald. Bob Prange comments that the sun-exposed, red pigmented side actually has more chlorophyll than the shaded side, even though it does not look that way. Gene Kupferman makes the point that Granny Smith apples have scald all over, whereas fruit of Red Delicious tend more to develop scald on the shaded side. Dave Rudell makes point that Granny's are grown in a hedge so they are in the shade. Granny's with a blush will not scald as much on the sun-exposed side. Cindy Tong asks if anyone has looked at UV to prevent scald. Dan MacLean replied he conducted a small experiment using paper to cover one side and put them under UV.

Dan also explored use of tobacco rattle virus for virus induced gene silencing in pome fruits. Post transcriptional gene silencing technique. Tried to put the PAL gene into fruit. The method caused some damage to fruit with the vacuum infiltration. Now going to try to work with leaves to see if apple is susceptible to infection by this virus. It is a useful and easy tool if it will work. Might be able to work with it postharvest. John Labavitch states that they might use this method to study genes encoding cell wall enzymes in tomato fruit.

John Labavitch (CA) – Investigating cell wall metabolism in ripening boysenberries, raspberries and blueberries. In boysenberries there is overlap between fruit expansion and fruit softening. Tried to describe what happens in the cell wall during softening of these fruits. Now recognized that a turgor component of softening has to be taken into account. Pectin polymer size changes during berry softening are dramatic. Three papers are in press. Study on fruit interactions with pathogens. In many cases pathogens will infect and grow on ripe fruit but not on unripe fruit. Polygalacturonase (PG) suppressed tomatoes show some decrease in susceptibility to pathogens during ripening. Generated suppressed lines for expansin, PG or both. Pathogen develops early on wild type and reduced expansin fruit, but on fruit from the PG plus expansin suppressed lines infection occurs much later. The double transgenics have much less mold than controls and are a little firmer. Possible that there is less useful substrate for pathogen growth. The double silenced fruit tasted like normal wild type tomatoes. Time to the different color stages is pretty uniform.

Beth Mitcham (CA) – Examining peach, almond, and related species as mutual sources of useful genetic variation for fruit and nut quality. Candidate genes for fruit softening identified in genus Prunus. Volatile emission from apple peel analyzed. High levels of alpha-farnesene found. A low oxygen flush treatment changes volatiles profile. Low oxygen flush controlled the scald after 8 months in air storage in Granny Smith. Low oxygen also reduced ethylene production.

David Rudell (WA) - Bagged Granny Smith apples and treated with UV plus white light. Fruit turn red under this condition. Identified components affected by UV irradiation after harvest. ACC and malic acid decreased with light treatment. Irradiation caused a decrease in alpha-farnesene in this artificial system. Sorbitol increased and this may be cultivar specific. Principal components analysis is a data mining tool that was used. Cindy Tong asks if Dave is going to study metabolic fluxes and he is interested in that. This approach is like a snapshot of metabolite levels at a specific time point. Investigated metabolites of DPA in apple tissue in relation to development of browning during storage of Braeburn fruit. In this experiment 1-MCP did not influence the incidence and severity of tissue browning. Less recoverable DPA in 1-MCP treated

fruit than in untreated fruit, but no clear correlation with fruit injury and browning. Storage duration, air or CA, 1-MCP or not, seemed to have some influence. Found alpha-farnesene in cortical tissues.

Bruce Whitaker (USDA-MD) - Continued investigation of conjugated triene (CT) oxidation products of alpha-farnesene in relation to scald development. Found that same conjugated trienol isomers identified in scald-susceptible apples also accumulate in Anjou pears stored in air. Also tried to identify minor CTs in Granny Smith apple and Anjou pear. An aldehyde with a UV absorbance maximum at 281 nm is probably unstable so it could act as a triggering molecule to generate free radicals.

1-MCP treatment alters ethylene and alpha-farnesene production in green and red skin of scald susceptible and resistant apples at level of gene transcription. Scald susceptible Cortland and Law Rome and scald resistant Idared compared. CTs were much higher in scald susceptible fruit. Cortland starts to escape 1-MCP and accumulate CTs late in air storage. CTs in red tissue of control fruit were higher than in unblushed tissue of 1-MCP treated fruit. So there appears to be some protective factor in blushed tissue to negate the effects of CTs. High levels of ethylene correlated with high levels of alpha-farnesene production. Some of this is in the NY report as well as the USDA-MD report.

Studying role of sterol lipids in membrane function in ripening tomato fruit. Large increase in stigmaterol:sitosterol ratio occurs during ripening. This could alter fluidity of the plasma membrane. High proportion of stigmaterol correlated with membrane leakiness. This is a ripening specific change (very small change in non-ripening mutant fruit). Cindy Tong asks if this will change the turgor pressure in the cell. Bruce says he is unsure but it would not be surprising. Beth Mitcham asks if this could be related to chilling injury. Bruce says that a sudden change in membrane composition, including an increase in the stigmaterol:sitosterol ratio, occurs when chilled tomato fruit are re-warmed. Jim Mattheis asks if the change regularly occurs with normal ripening (yes but differs with cultivar). Henrik asks about the Arabidopsis and yeast mutants lacking sterol 22-desaturase activity. Pretty sure it is non-lethal.

Randy Beaudry (MI) - Nobuko (grad student) studied gene expression related to branched chain ester formation in apple. Branched chain aminotransferase identified for Jonagold. Some changes in pyruvate decarboxylase observed. Have been developing a microarray for analysis of expression of key genes in apple during growth and storage. This is available to anyone in NE-1018. Company will custom make them for different applications.

Evaluating fruit abscission among various apple species and cultivars. There are some *M. domestica* lines that do not abscise but many do. The smaller fruited varieties have less tendency to drop fruit. Generally speaking the higher the ethylene level the more abscission occurs, but this does not always hold. Jim Mattheis says this could be another example of metabolic differences between big and small fruit.

Bob Prange (NS) - Bob announces that Sylvia Blankenship is winning the ASHS research award and Penny Perkins-Veazie is going to be inducted as an ASHS fellow. Gene Lester is also getting a fellow award. Still studying soft scald and internal breakdown in Honeycrisp apple. Using chlorophyll fluorescence to detect senescing cells. New application is to track water loss in grapes. Slow drying of grapes is used to improve wine quality. They require a certain amount of water loss; 20-25% is optimum. This can be determined by monitoring changes in fluorescence. Method works regardless of the grape variety but only with green tissue. Cytoplasmic acidosis might play a key role and this will be tested.

Aya Akagi (OR) - Graduate studies at OSU with Henrik Stotz. Identification of ethylene response factors (ERF) and ethylene response elements (ERE). Worked with pears and used an approach to look at role of ethylene in *Botrytis cinerea* decay. Ethylene suppressed apples showed more infection. Ethylene is involved in defense response in fruits. *Botrytis* activates PR genes. Polygalacturonase inhibitor protein (PGIP) is independent from ethylene regulation.

Meeting adjourned at 5:50 p.m.

Sunday, July 15 - Meeting reconvened at 8:30 a.m.

Research overviews presented by new or pending members of the project.

Herb Aldwinckle (NY-Geneva) - A plant pathologist, producing apples resistant to fireblight and other diseases is main area of expertise. Still have a classic breeding program at Cornell NYSAES. Need to combine fireblight and scab resistance with apple quality attributes. Using a genomic approach to confer fireblight resistance. Gives some resistance to scab and rust as well. Have a small project on flowering genes. Putting a dental caries vaccine into apple as part of a collaborative effort. Geza Hrazdina has been working on genetic down regulation of ethylene production. Project not completely terminated since Geza retired. Upregulating quercetin synthesis in apples since quercetin has been shown to slow tumor growth. Achieved a 60-fold up regulation in petunia so are using a similar approach in apple. Have put this gene into Galaxy apple. It would help to have earlier flowering of the transformed plant. Want to be able to induce flowering in less than 1 year. Penny asks how apple compares to onion regarding quercetin levels. Herb says quercetin might be bitter and thus negatively impact fruit flavor at high concentrations. This flavonoid is also implicated in fireblight resistance.

Chris Walsh (MD) - Interested in food safety and microbes populating the outside of the fruit. Identifying microorganisms on the fruit skin. Totally different microbial community on organic compared with conventional fruit. Found *Erwinia* on the conventional block but not the organic block. This work differs from the major pursuits of the group project, but he is also interested in effects of preharvest factors on postharvest quality. Also works on mealiness in peaches and production of Gala apple. Non-target effects on fruit surface. Have already found some interesting organisms on the surface among 250 to 500 total. None so far have been identified as a known human pathogen. Conducting trials with some of the organic pesticides. Herb says that he has always wondered what microbes are introduced by pickers/workers. Also expanding into research on vegetables, comparing organic vs conventional.

John Labavitch states that biofuels research might need postharvest help in storing cull fruit or cereal. For processes involving conversion of lignocellulose there will have to be some sort of postharvest protocols developed. Group needs to think about massive quantities of harvested product.

Next year's meeting discussed. No meetings to combine with other than ASHS in Orlando, FL. There will be a symposium along with the UC-Davis postharvest short course in honor of Adel Kader's retirement. Cindy Tong says group can come to Minnesota. Could do a Honeycrisp orchard tour. Slight edge to the southern Atlantic coast option over Minnesota after a vote. Indian River area might be a good choice. Possibly someone in Florida at UF or with USDA-ARS at Winter Haven or Fort Pierce could suggest a location. Chris Walsh says that he goes

down to Florida often and he could help set something up. Consensus reached on wording of four objectives to be the focus of the new project proposal.

Meeting adjourned 11:30 a.m.