FINAL PROJECT REPORT **YEAR:** 3 of 3

Project Title: Deliver 1-MCP treated d'Anjou pears with predictable ripening capacity

PI: Yan Wang
Organization: OSU MCAREC
Telephone: 541-386-2030 (214)
Email: yan.wang@oregonstate.edu
Address: 3005 Experiment Station
Address 2:
City/State/Zip: Hood River/OR/97031

Cooperators: Xingbin Xie, jiankun Song, David Sugar, Paul Chen, Nate Reed (AgroFresh Inc.)

Total Project Request: **Year 1:** $25,613 **Year 2:** $25,777 **Year 3:** $26,461

Other funding sources: None

Budget 1
Organization Name: Agricultural Research Foundation **Contract Administrator:** L.J. Koong
Telephone: 541-737-4066 **Email address:** l.j.koong@oregonstate.edu

Item	2012	2013	2014
Salaries		15,450[5]	15,914[5]
Benefits		7,327	7,547
Wages	15,000[1]		
Benefits	7,113[2]		
Equipment			
Supplies	3,000[3]	2,500	2,500
Travel	500[4]	500	500
Miscellaneous			
Total	25,613	25,777	26,461

Footnotes:
[1]Wages: 500hr each for 2 part-time employees at $10/hr and $20/h, respectively. 3% increase is factored into Year 2 and 3.
[2]OPE: $10/hr Temp employee calculated at 8.47% +2.43/mo., $20/hr Unclassified Employee calculated at 28.57%+$1230.51 per month. Both have a 3% increase per year.
[3]Supplies: maintaining cold rooms, buying fruit, gases (helium, nitrogen, hydrogen, air, and standard gases), gas tank rental, and chemicals.
[4]Travel: field trips to packinghouses and orchards.
[5]Salaries for Postdoctoral Research Associate (Xingbin Xie)

OBJECTIVES

The goal of this project was to develop commercial protocols for controlling postharvest disorders of pears through postharvest application of 1-MCP at commercially manageable dosage (100-300ppb) while allowing ripening to outstanding eating quality. The following strategies were investigated:

1. Storing 1-MCP treated ‘Anjou’ pears at elevated storage temperatures
2. Simultaneous application of 1-MCP and ethylene
3. Post-storage conditioning by ethylene, intermediate temperature, and other ripening compounds
4. Delaying 1-MCP application
5. Late harvest maturity and production elevation

SIGNIFICANT FINDINGS

1. Ripening capacity (RC), superficial scald (SS) inhibition, storage quality, ethylene production, and related gene expressions in 1-MCP treated ‘Anjou’ pears were affected by storage temperature, simultaneous application of 1-MCP and ethylene, post-storage ethylene conditioning (PSEC), post-storage intermediate temperature conditioning (PSITC), and orchard elevations.

2. 1-MCP treated ‘Anjou’ pears did not restore RC in 7d at 68°F following 8 months of storage at 30°F. The 1-MCP treated fruit that were stored at 34°F developed RC with minimal SS in 7d at 68°F following 5-8 or 6-8 months depending on production year. Low O_2 at 2% slowed down the losses of green color, flesh firmness (FF), and titratable acidity (TA) of the 1-MCP treated fruit during storage at 34°F. The 1-MCP treated fruit lost green color and FF quickly (i.e., after 3-4 months) during storage at 36°F.

3. Simultaneous application of 1-MCP and ethylene at 1:1-2 (i.e., 300:300-600ppb) allowed the 1-MCP treated ‘Anjou’ pears developing RC with minimal SS following 5-8 or 6-8 months (depending production year) of storage at 30°F.

4. PSEC and PSITC could ripen 1-MCP treated red (Columbia) ‘Anjou’ following 5-8 months of storage at 30°F. 1-MCP treated green ‘Anjou’ could be ripened by PSEC or PSITC only after 8 months of storage at 30°F. Ethylene is the most efficient ripening compound and other ripening compounds including abscisic acid, jasmonic acid, methyl jasmonate, salicylic acid … may not be effective on ripening 1-MCP treated ‘Anjou’ pears.

5. Delaying 1-MCP application after harvest may not be a useful protocol for ripening 1-MCP treated ‘Anjou’ pears following cold storage. Fruit treated with 1-MCP within 3 weeks after harvest did not develop RC for 8 months, but fruit treated with 1-MCP between 3-4 weeks after harvest developed unacceptable SS following 4-8 months of storage at 30°F.

6. Green ‘Anjou’ pears from high elevations are less responsive to 1-MCP than that from low elevations. 1-MCP treated green ‘Anjou’ pears that were from orchards at high elevations (i.e., 2000ft) could be ripened by PSEC and PSITC without affecting SS following 5-8 months of storage at 30°F.

7. Regarding RC, there were no differences in responsiveness to 1-MCP between harvest maturities (H1 = 15lb, H2 = 13lb, H3 = 12.5lb) of ‘Anjou’ pears following storage at 30°F.

METHODS

Defect-free fruit were packed into 20kg wooden boxes with perforated polyethylene liners. Packed fruit were immediately transported to MCAREC and stored at 30°F. 1-MCP (SmartFresh: AgroFresh, Spring House, PA, USA) treatment at 100-150ppb was carried out according to procedures provided by the manufacture in an air-tight $40M^3$ room at 32°F for 24h on the second day after harvest. An electronic fan was used to circulate the air in the treating room.

1. Storage temperature

After ventilation, 1-MCP treated fruit were transferred to storage rooms at 30°F, 34°F, and 36°F. Control fruit were included in each storage temperature. After each month of cold storage, fruit IEC (internal ethylene concentration), storability [fruit firmness (FF), skin color], superficial scald related chemistry [FAR (α-farnesene) and CTols (conjugated trienoles)], and ripening-related gene expression were evaluated after 1d at 68°F, and fruit ripening capacity [FF, EJ (extractable juice), SSC (soluble solid content), TA (titratable acidity)] and superficial scald were evaluated after 7d at 68°F. Transcript levels of ethylene biosynthesis and signal genes were analyzed. The aim was to determine the genes that regulate the recovery of ripening capacity in 1-MCP treated 'Anjou' pears.

2. Exposure fruit to 1-MCP and ethylene simultaneously

Immediately after exposure of fruit to 1-MCP at 300ppb, a calculated amount of ethylene (300, 600, 1500ppb) was injected into the air-tight $40M^3$ room at 32°F. Fruit were treated with 1-MCP and ethylene simultaneously for 24h. After ventilation, the treated fruit were transferred to a storage room at 30°F. Fruit evaluations were the same with described in 1.

3. Post-storage conditionings

After each month of cold storage, 1-MCP treated green and red (Columbia strain) 'Anjou' fruit were moved to an air-tight ethylene ripening room with ethylene concentration at 100ppm at 68°F for 48h, or transferred to an ethylene-free room at 50°F for 15d, or dipped in solutions of abscisic acid (ABA), jasmonic acid (JC), methyl jasmonic (JA), salicylic acid (SA), RC-2…… at recommended concentrations for 1-24h following cold storage. Then, fruit were transferred to 32°F for 2 weeks. RC and SS were evaluated after 7d at 68°F.

4. Delayed 1-MCP treatment

Fruit were exposed to 1-MCP at 100-150ppb at 1, 2, 3, 4-weeks-delay-after-harvest in an air-tight $40M^3$ room at 32°F for 24h. After ventilation, treated fruit were transferred to a storage room at 30°F. Fruit evaluations were the same as described in 1.

5. Harvest maturity and production elevation

Fruit were harvested at 3 maturities: H1 = 14.5-15lbf, H2 = 13lbf, and H3 = 12.5lbf from two orchard elevations (500ft and 2000ft). The 1-MCP treated fruit were stored at 30°F. RC and SS were evaluated after 5-8 months of storage.

RESULTS AND DISCUSSION

1. Elevated storage temperatures

When stored at 36°F, 1-MCP treated 'Anjou' pears softened and yellowed quickly after 3-4 months in storage and developed dry-coarse texture after ripening. Regarding RC following 8 months of cold storage, fruit harvested at the late maturity (FF = 12.5lb) did not differ from the commercial harvest maturity (FF = 15-13lb) in responding to 1-MCP. Therefore, data of 1-MCP treated fruit stored at 36°F and 1-MCP treated fruit that were harvested at late maturity are not presented in this part.

1.1. Ethylene production and respiration rate

Control fruit started accumulating IEC after 2 months, and thereafter IEC reached the highest amount at 3 months, and maintained > 2ppm for 8 months at 30°F. 1-MCP treated fruit stored at 30°F had extremely low IEC (< 0.2ppm) throughout 8 months of storage. In contrast, the 1-MCP treated fruit that were stored at 34°F started accumulating IEC after 5 months, and thereafter increased continuously between 5 to 8 months of storage (Fig. 1). Ethylene production rate increased significantly after 2 months, reached a maximum value after 5 months, and thereafter decreased. 1-MCP treated fruit that were stored at 30°F showed no ethylene production following 1-8 months of storage. 1-MCP treated fruit stored at 34°F showed no ethylene production for 3 months, then started to produce ethylene at a low rate following 4 and 5 months, and produced a significant amount of ethylene after 6 months of storage (Fig. 1). The respiration rate of control fruit increased during 8 months of storage and was higher than that of 1-MCP treated fruit stored either at 30°F or 34°F during 1-8 months of storage. 1-MCP treated fruit stored at 30°F maintained the lowest respiration rate which remained stable during 8 months of storage. 1-MCP treated fruit stored at 34°F had a low but significantly higher respiration rate than 1-MCP treated fruit stored at 30°F in the first 5 months, and increased significantly after 6 months of storage (Fig. 1).

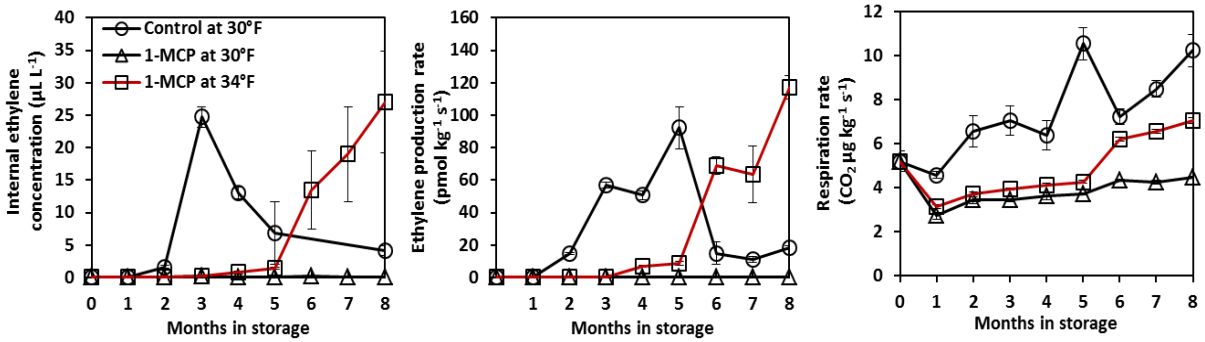


Fig. 1. Internal ethylene concentration, ethylene production rate, and respiration rate following storage of 1-MCP treated 'Anjou' pears at 30 or 34°F for 8 months.

1.2. Storability

1-MCP treated fruit that were stored at 30°F developed non-measurable IEC and ethylene production rate, therefore, maintained FF, skin color, and TA with minimum reductions for 8 months of storage. 1-MCP treated fruit stored at 34°F maintained FF for 7 months, however, decreased skin green color after 5 months and FF after 8 months of storage (Fig. 2).

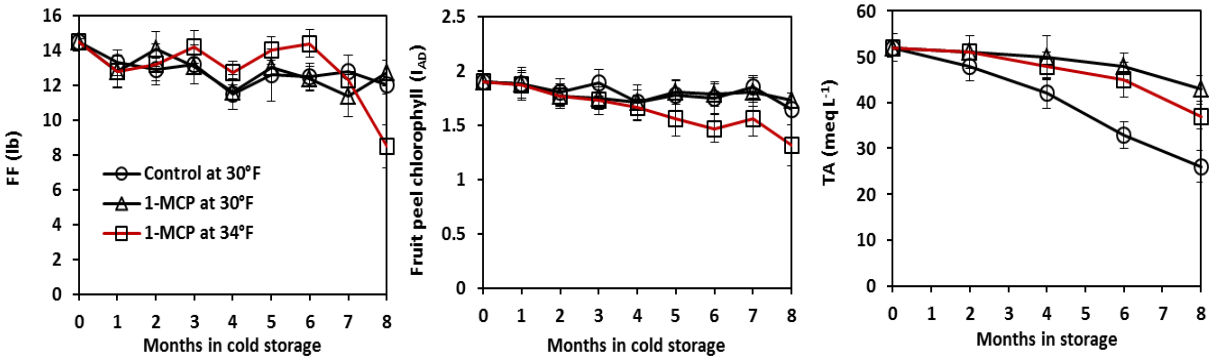


Fig.2. Effect of storage temperatures on storability of 1-MCP treated 'Anjou' pears.

1.3. Ripening capacity and superficial scald development in 7d at 68°F following cold storage

For 'Anjou' pears, we found that the buttery-juicy texture is related to fruit FF < 5-6lb with extractable juice (EJ) content on a fresh weight basis of < 650 mL kg^{-1}. 1-MCP treated fruit stored at

30°F developed neither RC nor SS in 7d at 68°F following 3-8 months of storage. The 1-MCP treated fruit stored at 34°F developed RC (FF < 5-6lb with EJ < 650 mL kg^{-1} in 7d at 68°F) after 5 and 6 months, in 2011 and 2012, respectively. It took 2 and 3 months of cold storage to fulfill the chilling requirement for developing RC of the control fruit in 2011 and 2012, respectively. 1-MCP treated fruit that were stored at 34°F developed minimal severity and incidence of SS in 7d at 68°F following 5-8 months of cold storage (Fig. 3).

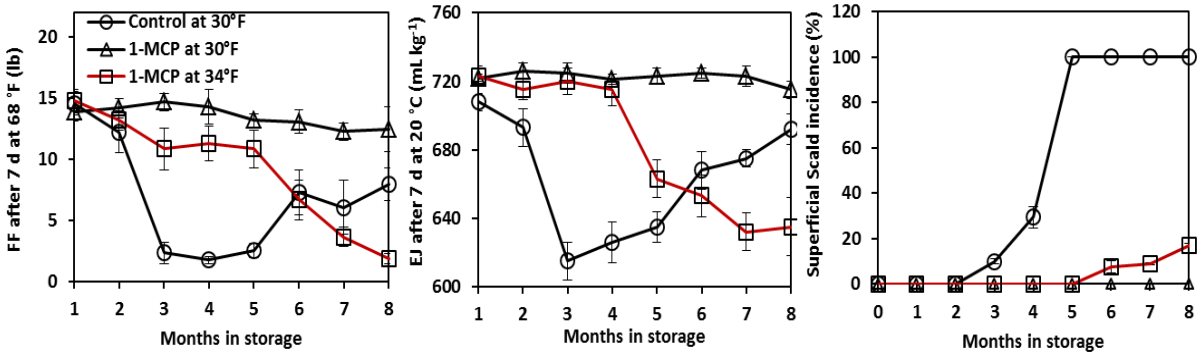


Fig. 3. Effect of storage temperatures on ripening capacity expressed as fruit firmness (FF) and extractable juice (EJ) and superficial scald (SS) incidence of 1-MCP treated 'Anjou' pears in 7d at 68°F following cold storage.

1.4. Ripening capacity related gene expressions

Compared to the control, the expression of ethylene synthesis (*PcACS1*, *PcACO1*) and signal (*PcETR1*, *PcETR2*) genes was stable at extremely low levels in 1-MCP@30°F fruit. In contrast, they increased expression after 4 or 5 months of storage in 1-MCP@34°F fruit. Other genes (*PcCTR1*, *PcACS2*, *PcACS4* and *PcACS5*) remained at very low expression regardless of fruit capacity to ripen. Therefore, the recovery of ripening capacity in 1-MCP treated 'Anjou' fruit was regulated by ethylene synthesis and signal genes *PcACS1*, *PcACO1*, *PcETR1 and PcETR2*.

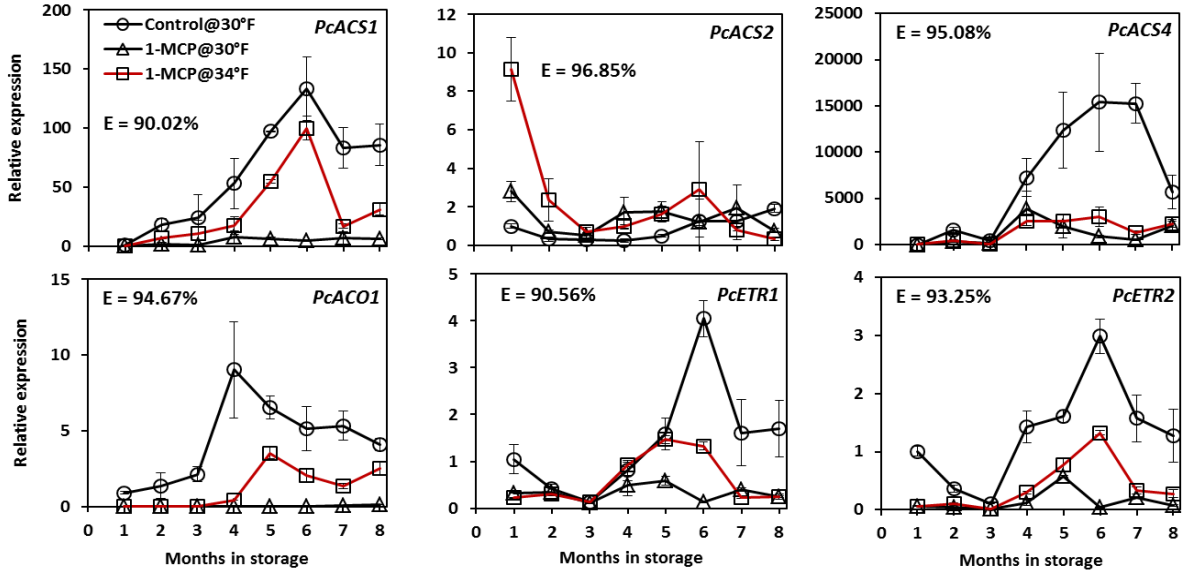


Fig. 4. Transcript levels of ethylene synthesis and signal genes in 1-MCP treated 'Anjou' pears stored at 30°F (1-MCP@30°F) and 34°F (1-MCP@34°F).

1.5. 1-MCP + Low O_2 (2%) storage

Low O_2 at 2% slowed down the losses of green color, FF, and TA without affecting RC (FF < 5-6lb with EJ < 650 mL kg^{-1} in 7d at 68°F) of 1-MCP treated fruit stored at 34°F for 8 months (Table 1). SS

incidence was 8.2% and 5.9% in RA and 2% O_2, respectively, after 8 months of storage at 34°F.

Table 1. Fruit storage quality [peel color, fruit firmness (FF), titratable acidity (TA)], ripening capacity [FF and extractable juice (EJ)], and superficial scald (SS) of 1-MCP treated 'Anjou' pears following 8 months of cold storage at 30 or 34°F in regular air (RA) or low O_2 storage.

	Peel color			after 7 d at 68 °F		
	(hue)	FF (lb)	TA (%)	FF (lb)	EJ (mL kg^{-1})	SS (%)
Control at 30°F in RA	91.4a	14.2a	0.20c	5.3b	686b	100a
1-MCP at 30°F in RA	92.0a	14.5a	0.27a	11.6a	710a	0c
1-MCP at 34°F in RA	88.3c	11.1c	0.24b	3.8c	640c	8.2b
1-MCP at 34°F in 2%O_2	90.8b	13.6b	0.26a	3.2c	639c	5.9b

Different letters indicate significant differences between treatments at each evaluation according to Fisher's protected LSD test at $p = 0.05$.

2. Simultaneous application of 1-MCP + ethylene at 1:1-5 (300:300, 600, 1500ppb)

2.1. Ethylene production and respiration rate

1-MCP at 300ppb totally shut down ethylene production and reduced respiration rate significantly during 8 months of storage at 30°F. Fruit received simultaneous application of 1-MCP + ethylene at 1:1-2 started to increase IEC, ethylene production rate, and respiration rate after 4 months of cold storage. Compared to control, simultaneous application of 1-MCP + ethylene at 1:5 had a little effect on IEC, ethylene production rate, and respiration rate of 'Anjou' pears during cold storage (Fig. 5).

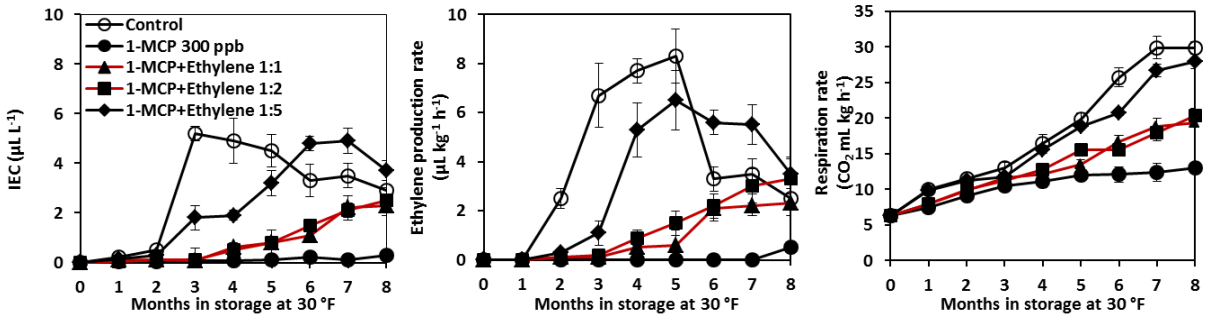


Fig. 5. Effect of simultaneous application with 1-MCP + ethylene on internal ethylene concentration (IEC) and respiration rate of 'Anjou' pears during storage at 30°F.

2.2. Storability

Simultaneous application of 1-MCP + ethylene at 1:1-2 maintained fruit firmness, skin green color, and TA the same as 1-MCP at 300ppb for 8 months of storage at 30°F. Compared to the control, the treatment of 1-MCP + ethylene at ratio of 1:5 did not affect fruit storability (Table 2).

2.3. Ripening capacity and superficial scald development in 7d at 68°F following cold storage

Fruit received simultaneous application of 1-MCP + ethylene at 1:1-2 developed RC with FF less than 5-6lb and extractable juice less than 650 mL kg^{-1} in 7d at 68°F following 5-8 months of storage at 30°F. Fruit received simultaneous application of 1-MCP + ethylene at 1:5 developed RC following 3-5 months, but developed dry-coarse texture indicated by EJ > 650 mL kg^{-1} following 6-8 months of cold storage. Fruit received simultaneous application of 1-MCP + ethylene at 1:1-2 produced higher amount of α-farnesene and CTols than 1-MCP treated fruit but much less than control, and therefore developed minimal amount and severity of SS in 7d at 68°F following 5-8 months of storage at 30°F.

Fruit received simultaneous application of 1-MCP + ethylene at 1:5 developed unacceptable SS following 3-8 months of cold storage (Fig. 6).

Table 2. 'Anjou' fruit storage quality affected by simultaneous application of 1-MCP + ethylene at ratio of 1:1-5 after 5 and 8 months of storage at 30 °F.

	5 months				8 months			
	Peel color (hue)	FF (lb)	SSC (%)	TA (%)	Peel color (hue)	FF (lb)	SSC (%)	TA (%)
Control	96.3a	14.5a	12.4a	0.29b	91.4b	13.9b	12.3a	0.19b
1-MCP 300 ppb	97.1a	14.8a	12.5a	0.32a	92.5a	14.5a	12.5a	0.27a
1-MCP+Ethylene 1:1	97.0a	14.7a	12.6a	0.31a	91.9ab	14.5a	12.3a	0.25a
1-MCP+Ethylene 1:2	96.8a	14.6a	12.6a	0.31a	92.1ab	14.4a	12.4a	0.25a
1-MCP+Ethylene 1:5	96.4a	14.6a	12.4a	0.28b	91.5b	14.0b	12.5a	0.22b

Different letters indicate significant differences between treatments at each evaluation according to Fisher's protected LSD test at $p = 0.05$.

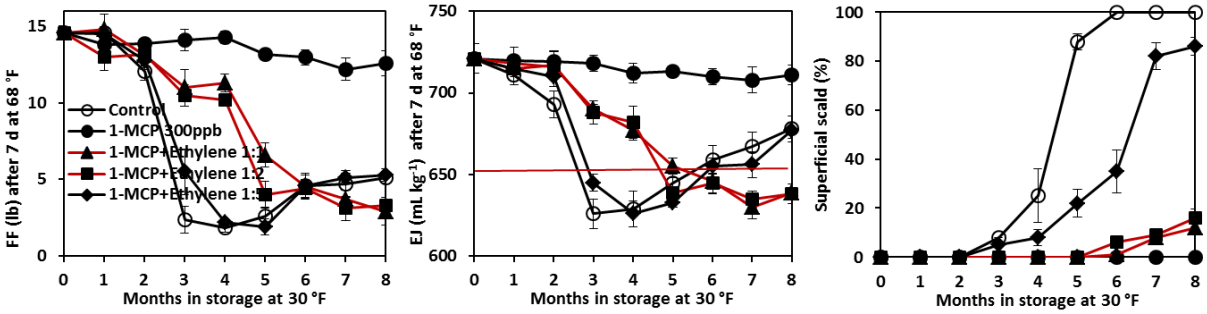


Fig. 6. Effect of simultaneous application of 1-MCP + ethylene on fruit firmness (FF), extractable juice (EJ), and superficial scald in 7d at 68°F following cold storage at 30°F.

3. Post-storage conditionings

3.1. Post-storage ethylene conditioning (PSEC)

Ethylene production rate of 1-MCP treated green 'Anjou' did not response to PSEC following 1-7 months, but increased following 8 months of storage at 30°F. In contrast, the ethylene production rate of 1-MCP treated red 'Anjou' (Columbia) increased in responding to PSEC following 5-8 months of cold storage. In consequence, PSEC could not ripen the 1-MCP treated green 'Anjou' following 1-7 months, excepting after 8 months of storage at 30°F. In contrast, the commercially standard PSEC could ripen 1-MCP treated red 'Anjou' following 5-8 months of storage at 30°F. 1-MCP controlled SS in both green and red 'Anjou' pears during 8 months of storage at 30°F. PSEC did not affect SS development in green and red 'Anjou' (Fig. 7).

PSEC up-regulated *PcACO1* and *PcETR2*, had no effect on *PcACS5*, and down-regulated the other genes in 1-MCP treated red 'Anjou', while it down-regulated all the genes in 1-MCP treated green 'Anjou'. *PcACO1* may play an important role in initiating ripening capacity in 1-MCP treated red 'Anjou' pear upon PSEC treatment. The anthocyanin synthesis may influence ethylene metabolism in the response of pears to 1-MCP (Fig. 8).

3.2. Post-storage intermediate temperature conditioning (PSITC)

PSITC (for 15d at 50°F) had a similar effect with PSEC on ethylene production, RC, and SS of 1-MCP treated green and red 'Anjou' pears following storage at 30°F (data not shown).

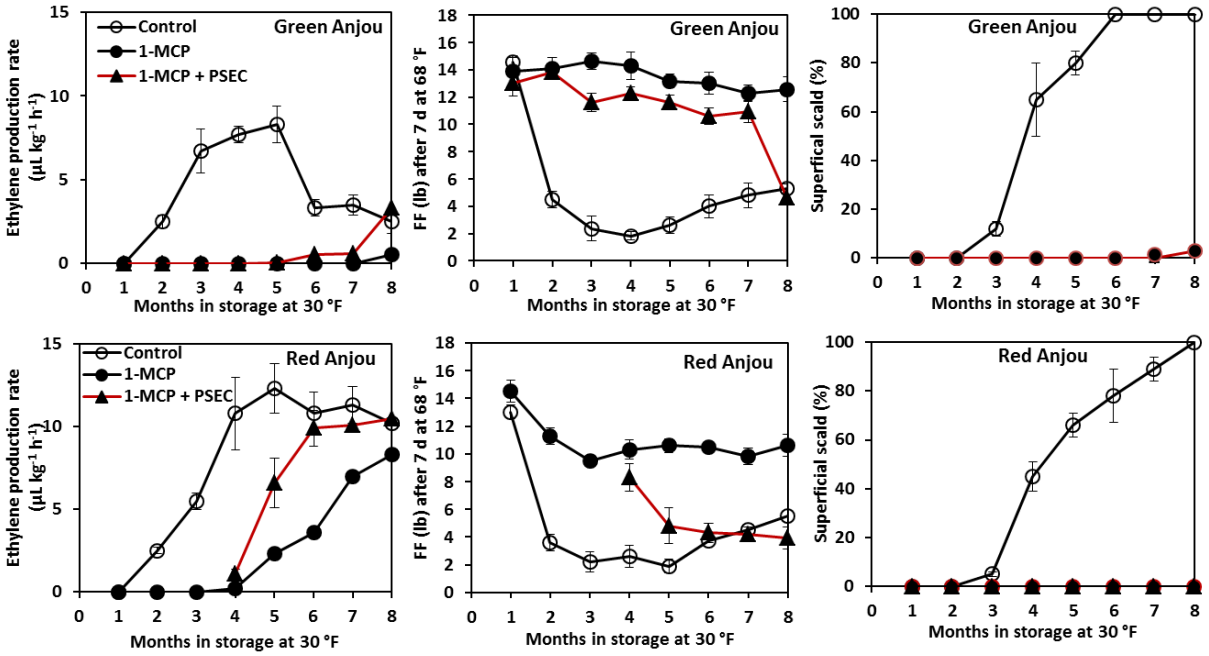


Fig. 7. Effect of post-storage ethylene conditioning (PSEC) on ethylene synthesis, ripening capacity and superficial scald of 1-MCP treated green and red 'Anjou' pears following storage at 30°F.

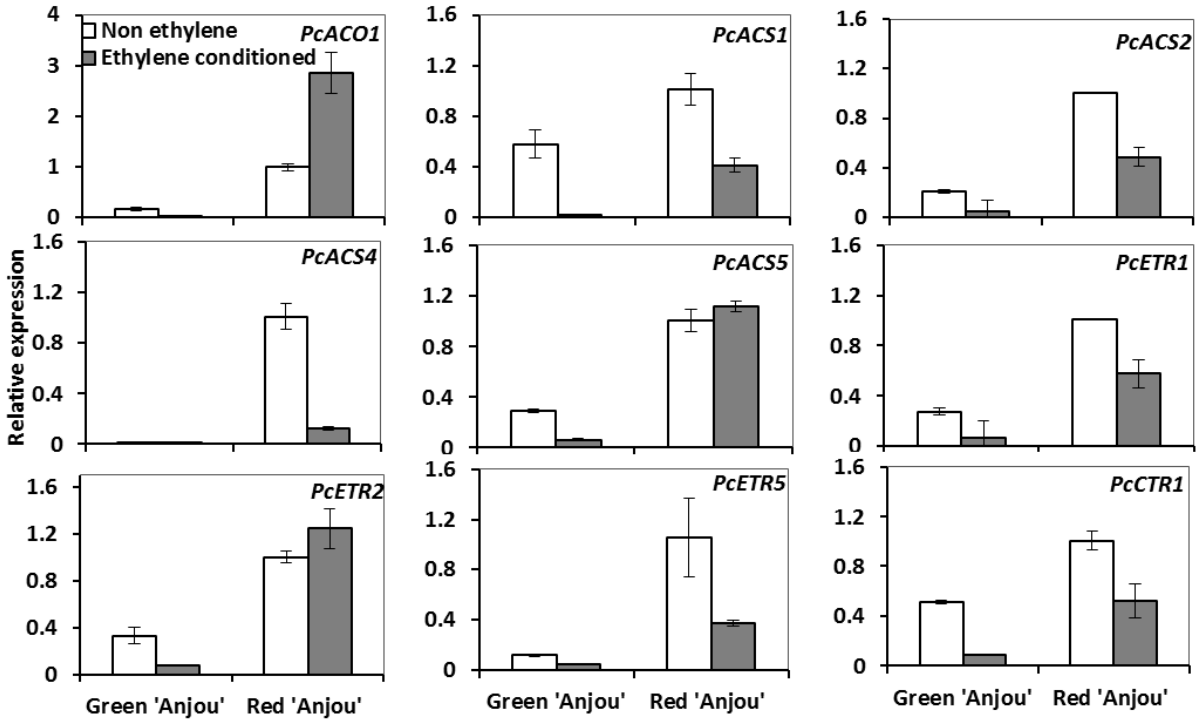


Fig. 8. Effect of post storage ethylene conditioning (PSEC) on transcript levels of ethylene synthesis (*PcACO1*, *PcACS1*, *PcACS2*, *PcACS4, and PcACS5*) and signal (*PcETR1*, *PcETR2*, *PcETR5*, and *PcCTR1*) genes in 1-MCP treated green and red 'Anjou' pears after 6 months of storage at 30°F.

3.3. Ripening compounds

The ripening compounds [abscisic acid (ABA), jasmonic acid (JA), methyl jasmonate (MJ), salicylic

acid (SA) ……] could not ripen the 1-MCP treated green ‘Anjou’ fruit to a buttery-juicy texture in 7d at 68°F following 3-8 months of storage at 30°F (Fig. 10). Ethylene was the most efficient compound to ripen the 1-MCP treated green and red ‘Anjou’ pears.

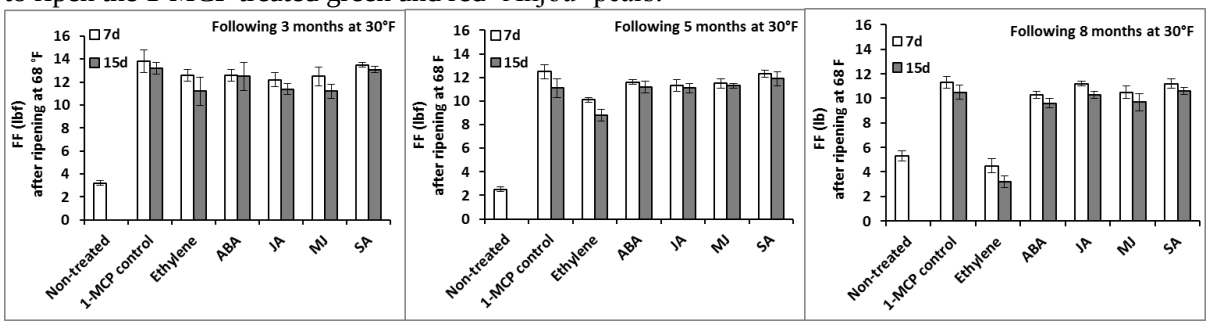
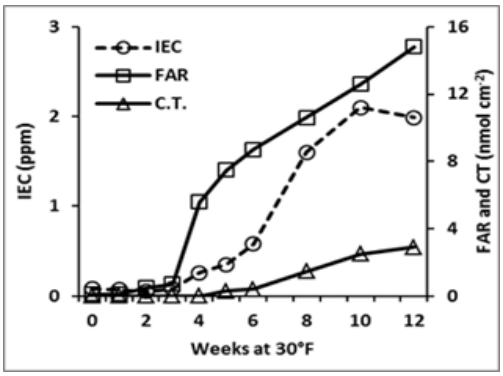


Fig. 10. Effect of ripening compounds: abscisic acid (ABA), jasmonic acid (JA), methyl jasmonate (MJ), salicylic acid (SA) on ripening capacity of 1-MCP treated ‘Anjou’ that were stored for 3, 5, or 8 months at 30°F.

4. Delaying 1-MCP treatment after harvest

The oxidation products (CTols) of FAR damage the hypodermal tissue of fruit and cause SS of pear and apple. Ethylene enhances FAR synthesis. 1-MCP controls scald of d’Anjou pears by inhibiting ethylene production, therefore, reducing productions of FAR and its oxidation products, CTols. Within the initial two months of cold storage at 30°F, Anjou pears developed IEC, FAR and CTols in a dynamic manner. IEC and FAR were determined to increase significantly after 3 weeks and CTols started to increase after 6 weeks.



In 2011, two delayed treatments: 2-weeks-delay and 4-weeks-delay were carried out. Results indicated that fruit treated with 1-MCP at 2-weeks-delay developed neither SS nor RC in 7d at 68°F following 3-8 months of storage at 30°F. In contrast, fruit treated with 1-MCP at 4-weeks-delay did not control SS during ripening following 4-8 months of storage. In 2012, we treated ‘Anjou’ with 1-MCP at 1, 2, 3, and 4 -weeks-delay after harvest and stored them at 30°F. Results indicated that fruit treated at 1, 2 or 3-weeks-delay develop neither SS nor RC in 7d at 68°F following 3-8 months of cold storage, in contrast, fruit treated at 4-weeks-delay developed unacceptable SS during ripening following cold storage (Fig. 11).

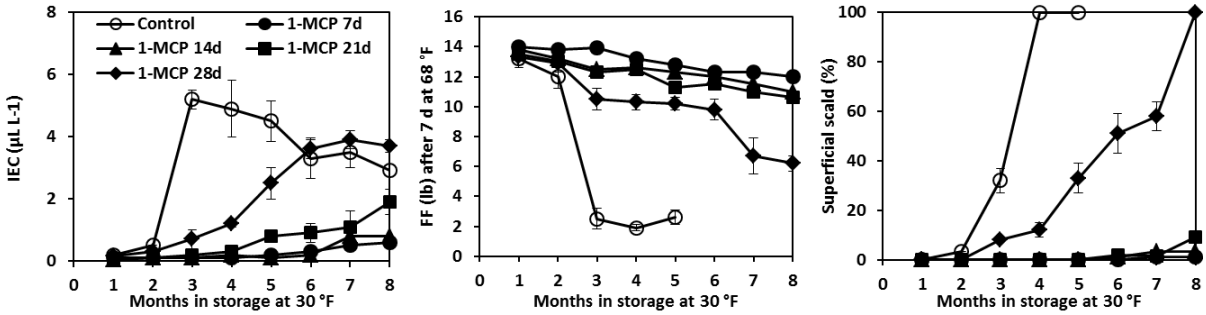


Fig. 11. Effect of delayed 1-MCP treatments after harvest on ripening capacity and scald development of 1-MCP treated ‘Anjou’ pears following cold storage 30°F.

5. Delaying harvesting

Regarding RC and SS, harvest maturity (H1= 15lb, H2 = 13lb) did not affect 'Anjou' pear' responsiveness to 1-MCP following storage at 30°F. 1-MCP treated 'Anjou' fruit that were harvested at H3 = 12.5lb developed RC following 7-8 months of storage at 30°F in 2011. However, the 1-MCP treated H3 fruit did not develop RC following 6-8 months of storage at 30°F in 2012 (Fig. 12).

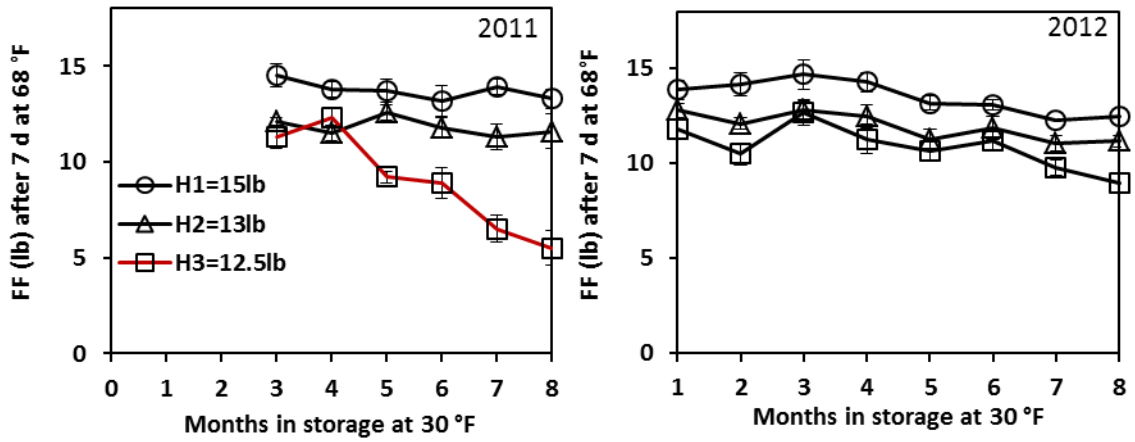


Fig. 12. Ripening capacity of 1-MCP treated 'Anjou' pears harvested at three maturities in two production years following 8 months of storage at 30 °F.

6. Production elevation

1-MCP treated 'Anjou' pears from orchard at 2000ft started to produce minimal amount of ethylene (< 0.1-1 µL kg^{-1} h^{-1}) after 5 months of storage at 30°F. However, the increased ethylene synthesis may not be high enough to trigger the RC. Both PSEC and PSITC enhanced ethylene production rate of the 1-MCP treated fruit following 5-8 months of cold storage. In consequence, the 1-MCP treated 'Anjou' pears developed RC upon PSEC or PSITC with minimal amount of SS (< 10%) following 5-8 months of storage at 30°F (Fig. 13).

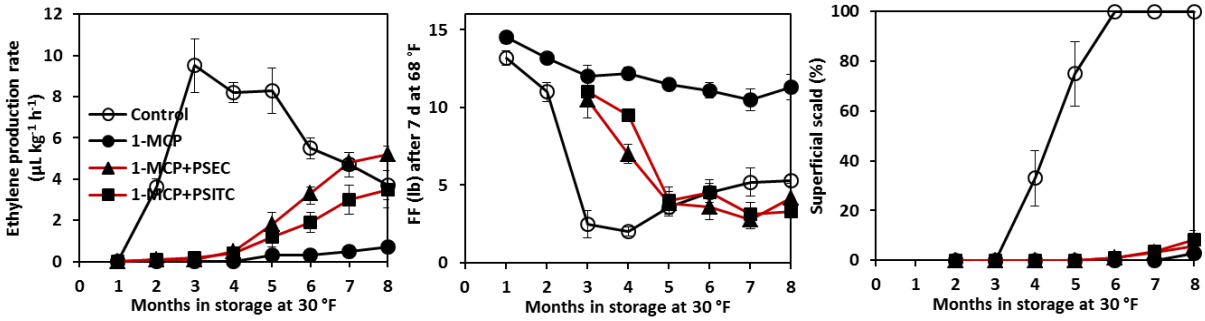


Fig. 13. Ethylene production rate, ripening capacity, and superficial scald of 1-MCP treated 'Anjou' pears from orchards at elevation of 2000ft affected by post-storage ethylene conditioning (PSEC) and post-storage intermediate temperature conditioning (PSITE) following 5-8 months of storage at 30°F.

EXECUTIVE SUMMARY

Project title: Deliver 1-MCP treated ‘d’Anjou’ pears with predictable ripening capacity

‘Anjou’ pear is the most produced pear cultivar in the Pacific Northwest of the US. It is enjoyed by consumers when fruit have ripened to a buttery and juicy texture at warm temperatures following cold storage. A peel disorder, superficial scald that appears during marketing following cold storage is a significant factor influencing postharvest management. The primary commercial control of scald on ‘Anjou’ pears at the present time is a postharvest treatment with the antioxidant ethoxyquin. In 2009, the European Union withdrew authorization for plant protection products containing ethoxyquin. Alternatives to ethoxyquin for controlling scald of ‘Anjou’ are needed. 1-Methylcyclopropene (1-MCP) is invaluable for controlling superficial scald and extending storage life of European pears, however it’s initiation of ripening capacity in treated fruit following cold storage has been a challenge to overcome. We found the following protocols may control scald and extend storage life of ‘Anjou’ pears through postharvest application of 1-MCP at commercially manageable dosage (100-300ppb) while allowing ripening to outstanding eating quality.

Storing the 1-MCP treated ‘Anjou’ pears at 34°F instead of 30°F
While 1-MCP treated fruit stored at 30°F did not develop ripening capacity due to extremely low internal ethylene concentration and ethylene production rate for 8 months, 1-MCP treated fruit stored at 34°F produced significant amounts of ethylene during storage and developed ripening capacity with relatively low levels of scald within 7 d at 68°F following 6-8 months of storage. 1-MCP treated fruit stored at 36°F lost green color and fruit firmness quickly during storage. In conclusion, 1-MCP treatment of ‘Anjou’ pears followed by storing at an elevated temperature of 34°F instead of the traditional storage temperature of 30°F may be used as an alternative to ethoxyquin treatment for controlling scald while maintaining ripening capacity after long-term storage (i.e., 6-8 months). ‘Anjou’ pears that were stored at 34°F, however, lost green color, firmness and TA during long-term storage. Low O_2 at 2% slowed down the losses of green color, firmness, and TA of the 1-MCP treated fruit during storage at 34°F.

Simultaneous application of 1-MCP + ethylene at 1:1-2 (300:300-600ppb)
‘Anjou’ fruit received simultaneous application of 1-MCP + ethylene at 1:1-2 increased ethylene production and respiration rate after 4 months of storage at 30°F. Fruit treated with 1-MCP + ethylene at 1:1-2 maintained green color and TA, and developed ripening capacity with minimal superficial scald following 5-8 months of storage at 30°F.

Post-storage conditioning by ethylene or intermediate temperature
Post-storage ethylene conditioning (PSEC) and post-storage intermediate temperature conditioning (PSITC) could ripen red but not green ‘Anjou’ without increasing scald following 5-8 months of storage at 30°F. PSEC is the commercial standard method at 100ppm ethylene for 48h at 68°F. PSITC refers to conditioning at 50°F for 10-15d. Ethylene is the most efficient ripening compound and other ripening compounds may not be effective in ripening 1-MCP treated ‘Anjou’ pears.

Both PSEC and PSITC could ripen the 1-MCP treated green ‘Anjou’ that were from orchards at high elevations (i.e., 2000ft) following 5-8 months of storage at 30°F.

Delaying 1-MCP treatment after harvest and delaying harvesting
Delaying 1-MCP treatment after harvest and delaying harvesting may not be commercially feasible protocols to ripen 1-MCP treated ‘Anjou’ pears while maintaining its efficacy on storage quality.