

Project title: Improving quality and reducing costs of Conference pear storage using SmartFresh™

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

- Improvement in the long-term-storage quality of Conference pears stored at -1.0°C may be achieved by application of half rate SmartFresh™

Background and expected deliverables

With the granting of an EAMU for SmartFresh™ (1-MCP) on pears, opportunities exist to explore the modification of existing storage recommendations for Conference pears. Early experience with SmartFresh™ on Conference has found that pears often fail to ripen properly after removal from store and in some cases have lost their ability to respond to ripening cues. Nevertheless subsequent experimental trials conducted on behalf of Agrofresh have indicated that by modifying storage temperature, or reducing application rates from the usual recommended concentration of 625 ppb to 325 ppb, Conference pears retain their ability to ripen. The introduction of a low concentration of external added ethylene during SmartFresh™ treatment has produced promising results.

The current recommendations for pear storage require rapid cooling to remove the field-heat and reduce fruit temperature to 4°C within two to three days of store loading followed by a further reduction to -1°C within seven to ten days of loading. In some cases rapid cooling to -1°C has been difficult to achieve, particularly in older stores. Such low storage temperatures can lead to fruit stalk end shrivel in some stores. To avoid this, bins can be covered but this further increases storage costs.

The introduction of new protocols to counteract the problems associated with SmartFresh™ and delayed ripening, offer the opportunity of further research to improve pear quality and extend storage-life.

It is worth researching the effect of reducing the dose of SmartFresh™ currently recommended (625 ppb), or to store at higher temperatures than currently recommended. Reducing the dose rate to 325 ppb has been found to be effective where pear maturity is clearly defined and pears are to be marketed after six and nine months storage.

The most effective protocol must evaluate not only the propensity to ripen ex-store, but also the amount of shrivel, background colour and the incidence of rotting, both ex-store and during shelf-life.

The effect on pear storage life of ethylene removal during storage has also be tested.

The project aims to improve fruit quality and reduce costs of Conference pear storage by using SmartFresh™. Key to achieving this aim will be the identification of protocols whereby pears retain their ability to ripen following SmartFresh™ treatment.

Specific objectives are:

1. To identify an optimum method of SmartFresh™ treatment and storage for Conference pears.
 - 1.1 To identify the optimum storage temperature following an application of SmartFresh™.
 - 1.2. To assess the effects of exposure of fruit to low concentrations of external ethylene in conjunction with SmartFresh™ treatment with a view to maximising the benefits of objective 1.1.
 - 1.3. To compare the effect of SmartFresh™ application with ethylene scrubbing during storage.
2. To quantify the economic benefits of the identified optimum method of post-harvest treatment and storage.
3. To disseminate results obtained through publications, the EMRA members day on fruit storage and training days where appropriate.

Summary of the project and main conclusions

Year 1 (2011-2012)

In the first year of the trial Conference pears were harvested from two orchards (referred to as Orchard 39 and Orchard 40) in Kent on the 1st September 2011 and transported to the Produce Quality Centre at East Malling Research. After 48 hours of cooling, SmartFresh™ was applied at the temperatures and application rates outlined in the table below with or without the addition of ethylene. In the first year ethylene scrubbing using sheets impregnated with E⁺ formulated palladium catalyst was also tested:

Treatment	Code	Temperature regime		
		-0.5 to -1°C	0.5 to 1.0°C	1.5 to 2.0°C
Control, no treatment	C	√	√	√
24 h treatment with SmartFresh™ (625 ppb)	A	√	√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 300 ppb ethylene.	B1		√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 600 ppb ethylene	B2		√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 900 ppb ethylene	B3		√	√
24 h treatment with SmartFresh™ (312 ppb)	D	√	√	√
Ethylene scrubbing by E ⁺ (palladium based) throughout storage period	E		√	√

The results from the 2011/2012 season indicated that extending the storage period for Conference pear beyond the existing six-month window is most likely to be achieved through storing at lower temperatures of 1°C or less. Two contrasting orchards were included in these trials. The effectiveness of SmartFresh™ varied according to orchard; SmartFresh™-treated fruit from Orchard 40 softened at a slower rate than Orchard 39.

Storage at 1.5-2.0°C led to a loss of firmness during prolonged storage in both orchards and SmartFresh™ failed to maintain firmness above the commercially acceptable threshold (60N) after three months of storage. More importantly, a rapid loss of background green

colour was observed in fruit from all treatments stored at 1.5-2.0°C along with a greater incidence of post-harvest rotting in fruit stored beyond three months. In addition, internal carbon dioxide injury was present in fruit inspected after nine months of storage.

The ex-store firmness of pears stored at 0.5-1.0°C and -0.5 to -1.0°C during the first six months of CA storage were similar and no treatment differences between SmartFresh™ and control fruit were observed. Maintaining the firmness of pears long-term required storage at the standard -0.5 to -1.0°C regime. However, there was little significant effect of SmartFresh™ on ex-store firmness of Conference pears during extended periods of storage.

The rate of softening of pears during the shelf-life period was influenced by SmartFresh™ and the duration of storage. Pears entering shelf-life after three months of storage exhibited a one to two day delay before changes in firmness were observed. Pears treated with SmartFresh™ (625 ppb) softened at a slower rate between two and six days. The delay in softening was more pronounced in fruits stored at lower temperatures. However, fruits from each treatment reached an eating quality firmness of 1.5 kg by between five and seven days. Pears entering shelf-life after six or nine months storage showed no delay in softening and at this stage in the storage life, SmartFresh™ was only marginally effective at delaying softening during shelf-life of pears from Orchard 40.

Year 2 (2012-2013)

In the second year of the trial, three separate orchards (BG, BE and LB) were selected and SmartFresh™-treatments were applied at two temperatures (-0.5 to -1.0°C and 0.5-1.0°C), in accordance with the treatment plan below.

		-0.5 to -1°C	0.5 to 1.0°C
Control, no treatment	C	√	√
24 h treatment with SmartFresh™ (625 ppb)	A	√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 300 ppb ethylene.	B1		√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 600 ppb ethylene	B2		√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 900 ppb ethylene	B3		√
24 h treatment with SmartFresh™ (312 ppb)	D	√	√
Ethylene scrubbing by Potassium Permanganate throughout storage period	E		√

Fruits were inspected for external and internal quality after three, six and nine months storage. After each inspection, fruits were subject to eight to twelve days of shelf-life testing at 18°C. Conference pears from the three orchards behaved in a similar fashion during storage. Results of these trials show that storage temperatures influence the rate of softening during shelf. In the absence of SmartFresh™, pears stored previously at -1.0°C softened more slowly during shelf-life than fruit stored at 0.5-1°C. The application of half-rate (325 ppb) SmartFresh™ to Conference pears stored at -1°C and +0.5-1°C slowed the rate of softening decline during shelf-life with fruit reaching an eating firmness of 1.5 kg after 8 days of shelf-life. Application of full rate SmartFresh™ (625 ppb) prevented ripening during shelf-life. This impedance could be overcome by the addition of a small dose of ethylene at the time of SmartFresh™ application, but we observed that ethylene treatments also increased the incidence of rotting.

The benefit of increasing the storage temperature for pears has yet to be evaluated fully. While raising storage temperatures may offer a cost saving to growers, it is important that

the quality of fruit is not compromised. Half-rate SmartFresh™ controlled the rate of softening during shelf-life of fruit stored at 0.5-1.0°C. However, after six months storage the incidence of rotting in pears (6.1%) was greater than the 2.7% rotting observed in fruit stored at -1.0°C.

The potential of extending the storage life of pears beyond the existing March/April termination date (six months) is only possible if the incidence of rotting can be controlled. In these trials, the amount of rotting in pears stored for nine months at -1.0°C reached 12 % and increased to 19.4% in fruit stored at +0.5-1.0°C. However, with pears stored for nine months at -1.0°C, the application of SmartFresh™ at half or full rate slowed the rate of softening during shelf-life and both SmartFresh™ treatments reduced the incidence of internal discolouration, while SmartFresh™ applied at half-rate provided fruit with a better eating quality.

The conclusion of these trials is that half-rate SmartFresh™ applied to fruit stored at -1.0°C can help to manage shelf-life ripening for fruits destined for storage until March/April (six months). While the use of SmartFresh™ to extend Conference pear storage beyond the current termination date looks promising, further studies are required to fully evaluate this treatment.

Conclusions

- Where fruits are destined for long-term (six months) storage at -0.5°C to -1.0°C then application of half rate SmartFresh™ can help manage the rate of softening during subsequent shelf-life.
- Storage of pears at -0.5 to -1.0°C beyond six months can lead to increased incidence of rotting and in some consignments increased internal browning which may be addressed by post-harvest drenching in Rovral.
- SmartFresh™-treatment of Conference pear fruit at 0.5-1.0°C has provided some promising results but further work needs to be replicated on a larger scale before any recommendations can be made.
- The higher rate of rot development in Pears stored at 0.5-1.0°C is a concern and needs to be addressed before storage at higher temperature is considered on a commercial basis.

Financial benefits

- Application of half rate SmartFresh™ can slow down the rapid decline in firmness during shelf-life.

Action points for growers

- Improvement in the long-term-storage quality of Conference pears stored at -1.0°C may be achieved by application of a half rate SmartFresh™.
- Fruits need to be of sufficient maturity, above 12.3% Brix before treating with SmartFresh™, to allow fruits to ripen fully on removal to shelf-life conditions.
- Early removal (December) from store of SmartFresh-treated fruit will result in fruit taking longer (10-12 days) for pears to achieve an acceptable eating quality firmness of 1.5 kg.

SCIENCE SECTION

Introduction

With the granting of an EAMU for SmartFresh™ (1-MCP) on pears, opportunities exist to explore the modification of existing storage recommendations for Conference pears. Early experience with SmartFresh™ on Conference has found that pears often fail to ripen properly after removal from store and in some cases have lost their ability to respond to ripening cues. Nevertheless, subsequent experimental trials conducted on behalf of Agrofresh have indicated that by modifying storage temperature, or reducing application rates from the usual recommended level of 625 ppb to 325 ppb, Conference pears retain their ability to ripen (Mark Tully *personal communication*). The introduction of a low concentration of externally added ethylene during SmartFresh™ treatment has also produced promising results.

The current recommendations for pear storage require rapid cooling to remove the field-heat and reduce fruit temperature to 4°C within two to three days of store loading followed by a further reduction to -1°C within seven to ten days of loading. In some cases, rapid cooling to -1°C has been difficult to achieve particularly in older stores. Such low storage temperatures can lead to fruit stalk end shrivel in some stores. To avoid this, bins can be covered but this further increases storage costs.

The introduction of new protocols to counteract the problems associated with SmartFresh™ and delayed ripening, offer the opportunity for further research to improve pear quality and extend storage-life.

It is worth researching the effect of reducing the dose of SmartFresh™ currently recommended (625 ppb), or to store at higher temperatures than currently recommended. Reducing the dose rate to 325 ppb has been found to be effective where pear maturity is clearly defined and pears are to be marketed after six and nine months storage.

SmartFresh™ inhibits ethylene from binding to receptors and slows down the ripening process. The introduction of low concentrations of ethylene at the same time as a SmartFresh™ treatment may allow activation of a limited number of receptors whilst SmartFresh™ binds to remaining receptors, slowing down that natural rate of ripening of pears during storage whilst allowing fruit to ripen fully during shelf-life. It is anticipated that this procedure will facilitate the use of higher storage temperatures and therefore save energy costs.

The most effective protocol must evaluate not only the propensity to ripen ex-store, but also the amount of shrivel, background colour and the incidence of rotting, both ex-store and during shelf-life.

The effect on pear storage life of ethylene removal during storage has also been tested using a new palladium-based absorbent that has previously been demonstrated to be capable of removing ethylene from the storage environment.

Project aim(s):

To improve fruit quality and reduce costs of Conference pear storage by using SmartFresh™. Key to achieving this aim will be the identification of protocols whereby pears retain their ability to ripen following SmartFresh™ treatment.

Project objective(s):

1. To identify an optimum method of SmartFresh™ treatment and storage for Conference pears.
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2. To quantify the economic benefits of the identified optimum method of post-harvest treatment and storage.
3. To disseminate results obtained through publications, the EMRA members day on fruit storage and training days where appropriate.

Materials and methods

Year 1

Conference pears from two orchards (referred to as '39' and '40') from the same farm were harvested on 1st September 2011, and transported to the Produce Quality Centre, East Malling Research, whereupon fruit were randomized and all damaged, diseased and misshapen fruit were discarded.

The storage treatments tested are summarized in Table 1. For each of treatments C, A, D and E, approximately 100 fruits were loaded into each of three replicate plastic crates for

each of the two orchards. An additional aspect of the trial was to investigate the impact of SmartFresh™ and storage temperature on disease development and spread in pears inoculated with *Botrytis*. Ten conference pears previously inoculated with spores of *Botrytis* conidia were evenly distributed in one crate per orchard per treatment.

One CA chamber (360 litre) was used for each of these treatments. Thus for each treatment there were two uninoculated boxes and one inoculated box for each of two orchards, giving a total of six boxes.

Treatments B1, B2 and B3 were carried out using orchard 39 only, without *Botrytis* inoculation and the treatments stored within common chambers. Thus there were two boxes per treatment at each temperature.

All fruit were subjected to forced air cooling for 36 hours prior to SmartFresh™ treatment for treatments A, B, D and E. SmartFresh™ was applied at a standard dose of 625 ppb, a half dose of 312 ppb, or full rate (625 ppb) treatment was combined with a small dose of 300, 600 or 900 ppb of ethylene (Orchard 39 fruit only). Untreated controls and an additional scrubbing treatment (E+) were also included.

Table 1: Summary of storage treatments tested year 1 (2011-2012)

Treatment	Code	Temperature regime		
		-0.5 to -1°C	0.5 to 1.0°C	1.5 to 2.0°C
Control, no treatment	C	√	√	√
24 h treatment with SmartFresh™ (625 ppb)	A	√	√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 300 ppb ethylene.	B1		√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 600 ppb ethylene	B2		√	√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 900 ppb ethylene	B3		√	√
24 h treatment with SmartFresh™ (325 ppb)	D	√	√	√
Ethylene scrubbing by E+ (palladium based) throughout storage period	E		√	√

Year 2

Conference pears from three orchards; Bewley G (BG), Bewley E (BE) and Little Birchams (LB) from the same farm were harvested during the week of 5th September 2012, and transported to the Produce Quality Centre, East Malling Research, whereupon fruit were randomized and all damaged, diseased and misshapen fruit were discarded.

The storage treatments tested are summarized in Table 2.

Table 2: Summary of storage treatments tested in year 2 (2012-2013)

Treatment	Orchards	Code	Temperature regime	
			-0.5 to -1°C	0.5 to 1.0°C
Control, no treatment	BG, BE, LB	1	√	
24 h treatment with SmartFresh™ (312 ppb)	BG, BE, LB	2	√	
24 h treatment with SmartFresh™ (625 ppb)	BG, BE, LB	3	√	
Control, no treatment	BG, BE, LB	4		√
24 h treatment with SmartFresh™ (312 ppb)	BG, BE, LB	5		√
24 h treatment with SmartFresh™ (625 ppb)	BG, BE, LB	6		√
Ethylene scrubbing by potassium permanganate	BG, BE, LB	7		√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 900 ppb ethylene	BG	8a		√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 600 ppb ethylene	BG	8b		√
24 h treatment with SmartFresh™ (625 ppb) in the presence of 300 ppb ethylene	BG	8c		√

BG = Bewley G, BE = Bewley E, LB = Little Birchams

CA conditions

CA conditions were maintained using an ICA 66 gas monitoring system with automatic injection of air and nitrogen to maintain CA. CA storage conditions of 2.0% O₂ <1% CO₂ were used for both years. O₂ concentrations were allowed to establish through respiration. Where final CA establishment was slow to achieve, some additional nitrogen flushing was used in cabinets once O₂ had depleted below 5%. CO₂ was maintained at <1.0% by the attachment of external Ca (OH)₂ (lime) scrubbers.

Quality assessments

Harvest maturity assessments of fruit were made by starch clearance, using iodine staining and colour assessment using a Minolta colour meter in Lab mode. Firmness was measured using a motorised penetrometer (Lloyd LRX) with an 8 mm probe, % brix was measured on pear juice samples and fruits were cut longitudinally to inspect for internal physiological disorders and internal rots. Percentage dry matter content and mineral analysis of fruit were also assessed at harvest.

Assessments were undertaken after three, six and nine months of storage. Two x 10 fruit samples were assessed for fruit quality for each orchard from each treatment, immediately on removal from CA storage. In addition a 25 fruit sample of pears from each orchard*treatment combination was subject to shelf-life assessment at 18°C where 5 fruits were removed after two, three, five, six and eight days of shelf-life to determine the length of time fruit took to reach an optimum eating quality firmness of 15N (1.5 kg).

Data was subject to a factorial based ANOVA using Genstat version 13.0.

Results

Year 1

Colour ex-store

Storage of pears at 1.5-2.0°C led to a rapid loss of the ex-store green colour which was not halted by the application of SmartFresh™. Storage at lower temperatures of 0.5-1.0 or the standard -0.5 to -1.0 retained background green colour for longer (Table 5).

Firmness-Ex-store

Data from the first year of this trial showed SmartFresh™ treatment provided only a minor benefit in maintaining fruit firmness during extended storage. The lack of treatment efficacy was most probably due to the high background ethylene concentration caused by rotting fruit. Storage temperature and orchard consignments had the largest effects on ex-store

firmness (Table 6) with pears from orchard 40 stored at the standard storage temperature of -0.5°C to -1.0°C maintaining the best firmness (57-65 N; 5.7-6.5 Kg). Fruit stored at the higher temperature of 1.5-2.0°C softened rapidly after three months storage. Storage at the intermediate storage temperature (0.5-1.0°C) slowed the rate of firmness decline, but firmness readings declined below commercially acceptable limits after three months of storage.

% Brix- Ex-store

There was no evidence that temperature or SmartFresh™ altered the soluble solid content of fruit during storage (Table 8).

Rotting-Ex-store

The incidence of rotting (*Botrytis cinerea*) was most prevalent after three months of storage. Pears from orchard 39 had a higher incidence of rotting than orchard 40 (Table 7). In general, storage at higher temperatures (1.5-2.0°C) resulted in a higher incidence of rotting. Application of full rate SmartFresh™ increased the incidence of rotting during storage in pears from orchard 39 but the effect was not replicated in the other orchard consignment.

% Shivel-Ex-store

Stalk-end shivel was most noticeable at lower temperature storage (-0.5 to -1.0°C) and pears from orchard 39 appeared to suffer from the greatest amount of shivel (Table 10). No effect of SmartFresh™ was observed on the incidence of shivel.

% CO₂-Injury – Ex-store

The incidence of internal CO₂-injury was observed in fruit stored for 9 months at 1.5-2.0°C but was absent from consignments stored at lower temperatures (Table 9). Pears from orchard 39 exhibited the highest incidence of the disorder and this was aggravated by the application of SmartFresh™ in pears stored at high-temperatures.

Ethylene application trial

Due to the rapid decline in firmness across all treatments, the application of small doses of ethylene at the time of SmartFresh™ application had no effect on fruit firmness but increased the incidence of rotting (10-22%) compared to the control (5-6%). The incidence of rotting (*Botrytis cinerea*) increased with storage temperature. In addition, to elevating rots, the addition of ethylene at the higher storage temperature led to an increase in internal CO₂-injury and internal breakdown of the flesh.

% Weight loss

Weight loss from fruit ranged from 0.6%-2.0% across treatments in fruit stored at -0.5 to -1.0°C and +0.5 to 1°C; there were no clear treatment effects on weight loss from pears from either orchard. At higher temperatures (1.5-2.0°C), the combination of additional ethylene at harvest and SmartFresh™ led to an increase in water loss (~5%) but this may be a direct result of an increase in rotting observed in these treatments.

Shelf-life

After three months storage at 1.5-2.0°C a delay 'lag phase' in softening of 1-2 days was observed in fruits stored across all treatment and temperature combinations (Fig 1A, 1D). Interestingly, once pears started to soften the rate of firmness decline was rapid. In later inspections (six & nine months) softening of pears commenced immediately upon entering shelf-life conditions, however, the rate of softening was more gradual, and the time to reach 1.5 kg (15 N) - considered to be optimum eating quality - was between six and seven days in each case (Fig 2A, 2D, 3A and 3D).

In general, pears from orchard 40 softened at a slower rate, during the early stages of shelf-life compared to fruit from orchard 39. However, the number of days taken to reach eating quality in both orchards was similar. Pears from orchards 39 and 40 treated with full rate SF, softened to 1.5 kg in seven days, compared to six days for the untreated fruit and fruit treated with half rate SmartFresh™. At higher storage temperatures, storage beyond three months led to a decline in ex-store firmness and rapid softening in shelf-life.

After three months storage at the intermediate storage temperature of 0.5-1.0°C, pears treated with SmartFresh™ (625 ppm) softened to 1.5 kg in seven days and SmartFresh™ (312 ppm) and control fruit within six days (Fig 1B, 1E). The effect of delayed softening by SmartFresh™ was not observed in shelf-life samples tested after six and nine months of storage.

Storage of SmartFresh™ treated pears at the standard storage temperature (-0.5 to -1.0°C) maintained ex-store firmness for longer and this was also transcribed into delayed softening rates during shelf-life. After three months storage, the length of time taken to reach an eating quality firmness of 1.5 kg was seven days for SmartFresh™ (625 ppb) treated pears from orchard 40 and six days for untreated control fruit. SmartFresh™ (312 ppb) treated fruit took between six and six and a half days to reach eating quality firmness (Fig 1C, 1F). The initial rate of softening in pears treated with full rate SmartFresh™ was slower in pears but increased during the later stages of shelf-life.

Softening patterns of fruit coming out of (-0.5 to -1.0°C) storage at six months were similar to earlier inspections but after nine months of storage, softening curves of all treatments were similar.

Scrubbing of ethylene with E⁺

Scrubbing of ethylene with E⁺ did not alter the softening rates of pears. However, measurement of ethylene within the chambers indicates that the formulation used in this trial was not effective in removing the ethylene.

Table 3: Harvest maturity of Conference pears from 2 orchards (39 and 40)

Orchard	Green	Yellow	Firmness	%SS	%DM
	Minolta -a	Minolta b			
39	-17.14	40.54	63.95	12.60	16.20
SE	0.44	0.355	1.75	0	0.47
40	-17.51	40.88	64.25	12.70	15.80
SE	0.125	0.24	0.45	0.1	0.11

Table 4 : Mineral nutrition profiles of fruit at harvest

Orchard	K mg/100g	Ca mg/100g	P mg/100g	B mg/kg	K/Ca ratio
39	118	14.0	11.8	1.3	8.4
40	130	14.9	11.6	1.5	8.7

All values are based on mg 100g⁻¹ except boron (mg kg⁻¹)

Table 5. Ex-store green colour (Minolta - a value, in L, a b mode) of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 ppb and 321 ppb)

Green colour		December	March	June	December	March	June
		Orchard			Orchard		
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	-8.6	-13.0	-8.0	-10.1	-11.2	-8.7
SF 625ppb	1.5-2.0°C	-9.0	-10.2	-7.5	-12.0	-10.3	-9.1
SF 312ppb	1.5-2.0°C	-10.9	-8.3	-9.8	-11.1	-8.8	-8.7
Control	0.5-1.0°C	-13.7	-12.7	-11.4	-14.9	-10.5	-12.1
SF 625ppb	0.5-1.0°C	-14.2	-11.4	-14.1	-14.4	-12.3	-12.6
SF 312ppb	0.5-1.0°C	-14.4	-11.3	-11.7	-13.3	-11.2	-11.5
Control	-1.0- -0.5°C	-14.6	-13.5	-14.7	-15.0	-12.4	-13.6
SF 625ppb	-1.0- -0.5°C	-14.3	-12.7	-13.4	-14.4	-13.2	-13.2
SF 312ppb	-1.0- -0.5°C	-13.8	-12.6	-13.1	-14.7	-12.6	-12.3

LSD_{0.05} for the interaction between treatment x temperature x inspection =1.64 on 54df

Table 6. Ex-store Firmness (N) of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 321 ppb)

Firmness		December	March	June	December	March	June
		Orchard			Orchard		
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	60	51	43	63	54	46
SF 625ppb	1.5-2.0°C	58	48	45	63	54	51
SF 312ppb	1.5-2.0°C	59	45	45	60	52	45
Control	0.5-1.0°C	62	57	52	62	56	54
SF 625ppb	0.5-1.0°C	58	55	54	63	57	58
SF 312ppb	0.5-1.0°C	60	53	52	60	55	55
Control	-1.0- -0.5°C	66	58	59	65	61	61
SF 625ppb	-1.0- -0.5°C	63	57	57	65	61	60
SF 312ppb	-1.0- -0.5°C	63	58	60	64	60	58

LSD_{0.05} for the interaction between treatment x temperature x inspection =2.72 on 54df

Divide by firmness values by 9.96 for conversion of Newtons to kg pressure

Table 7. Ex-store % rotting of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 312 ppb)

% Rots		6					
		3 months	6 months	9 months	3 months	6 months	9 months
		Orchard			Orchard		
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	0	5	6.6	0	0	5.8
SF 625ppb	1.5-2.0°C	0	10	2.7	0	10	3
SF 312ppb	1.5-2.0°C	0	10	10	5	10	0
Control	0.5-1.0°C	0	0	0	5	5	3.2
SF 625ppb	0.5-1.0°C	0	15	1.5	0	0	0
SF 312ppb	0.5-1.0°C	0	5	2	0	0	3.9
Control	-1.0- -0.5°C	0	5	3.8	0	0	2.2
SF 625ppb	-1.0- -0.5°C	0	10	2.6	0	5	5.3
SF 312ppb	-1.0- -0.5°C	0	5	3.2	0	0	0.8

LSD_{0.05} for the interaction between treatment x temperature x inspection =6.32 on 54 d

Table 8. Ex-store %Brix of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 312 ppb).

% Brix		December	March	June	3 months	6 months	9 months
		Orchard			Orchard		
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	13.4	12.7	12.8	13.1	12.4	12.5
SF 625ppb	1.5-2.0°C	13.4	13.6	12.8	13.2	13.0	12.4
SF 312ppb	1.5-2.0°C	13.4	13.3	12.3	13.3	12.7	12.4
Control	0.5-1.0°C	13.5	12.8	13.0	12.7	13.1	12.3
SF 625ppb	0.5-1.0°C	13.4	13.6	12.9	13.1	13.4	12.8
SF 312ppb	0.5-1.0°C	13.6	13.7	13.2	13.3	12.9	12.7
Control	-1.0- -0.5°C	12.9	14.1	13.0	12.8	13.0	12.6
SF 625ppb	-1.0- -0.5°C	13.0	13.8	13.4	12.6	13.3	13.5
SF 312ppb	-1.0- -0.5°C	13.4	13.6	13.3	13.0	13.1	13.2

LSD_{0.05} for the interaction between treatment x temperature x inspection =0.455 on 54 df

Table 9. Ex-store % CO₂-injury of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 312 ppb).

% CO ₂ - injury		Dec	April	June	Dec	April	June
		Orchard			Orchard		
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	0	0	25	0	0	10
SF 625ppb	1.5-2.0°C	0	0	5	0	0	10
SF 312ppb	1.5-2.0°C	0	0	10	0	0	10
Control	0.5-1.0°C	0	0	0	0	0	0
SF 625ppb	0.5-1.0°C	0	0	0	0	0	0
SF 312ppb	0.5-1.0°C	0	0	0	0	0	0
Control	-1.0- -0.5°C	0	0	0	0	0	0
SF 625ppb	-1.0- -0.5°C	0	0	0	0	0	0
SF 312ppb	-1.0- -0.5°C	0	0	0	0	0	5

LSD_{0.05} for the interaction between treatment x temperature and inspection =5.95 on 54 df

Table 10. Ex-store % Shivel of Conference pears stored at three temperatures (1.5-2.0°C, 0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 and 321 ppb).

% Shivel		6			9		
		3 months	months	9 months	3 months	6 months	months
		Orchard			Orchard		
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	0	0	10	0	5	10
SF 625ppb	1.5-2.0°C	0	0	0	0	0	0
SF 312ppb	1.5-2.0°C	0	0	0	0	0	5
Control	0.5-1.0°C	0	0	0	0	5	0
SF 625ppb	0.5-1.0°C	0	5	0	0	0	10
SF 312ppb	0.5-1.0°C	0	0	0	0	5	0
Control	-1.0- -0.5°C	0	5	15	0	0	5
SF 625ppb	-1.0- -0.5°C	0	0	15	0	10	10
SF 312ppb	-1.0- -0.5°C	0	0	10	0	5	0

LSD_{0.05} for the interaction between treatment x temperature and inspection =6.39 on 54 df

Table 11. The number of days taken to reach an eating quality firmness of 15N (1.5 kg) during shelf-life (18°C).

Days to reach 1.5 kg		Orchard			Orchard		
		3 months	6 months	9 months	3 months	6 months	9 months
Treatment	Temperature	39	39	39	40	40	40
Control	1.5-2.0°C	6	5	5.5	6	5	6
SF 625ppb	1.5-2.0°C	7	5	5.5	7	5	6
SF 312ppb	1.5-2.0°C	6	5	5.5	6	5	6
Control	0.5-1.0°C	6	6	6	6	6	6.5
SF 625ppb	0.5-1.0°C	6	6	6	6.5	6	7
SF 312ppb	0.5-1.0°C	6	6	6	7	6	7
Control	-1.0- -0.5°C	6	6	7.5	6	6	7.5
SF 625ppb	-1.0- -0.5°C	7	7	7.5	6.5	8	7.5
SF 312ppb	-1.0- -0.5°C	6	7	7.5	7	6	7.5

Results Year 2 (2012/2013)

The mineral analysis profiles of all three orchards (Table 12) suggested fruit was suitable for long-term storage. The higher calcium profiles of pears from Little Birchams reflected the smaller size of fruit from this orchard.

Table 12 : Mineral nutrition profiles of fruit at harvest

Plot	K mg/100g	Ca mg/100g	P mg/100g	B mg/Kg	K:Ca ratio
Bewley G	133.8	10.01	15.30	1.61	13.37
Bewley E	119.0	9.72	15.17	1.62	12.24
Little Birchams	142.8	12.03	15.29	1.51	11.87

Table 13: Harvest Maturity Data

Orchard	Firmness	Brix	Starch	Starch
	Max. Load (N)	% SS	ctifl apple	ctifl pear
Bewley G	67.92	12.45	5.80	2c
Bewley.E	64.45	12.95	4.40	2b
Little Birchams.	68.11	12.35	4.70	2b/c

The three orchards were of similar maturity at harvest (Table 13). % Brix was above 11% required for low-temperature storage. Moreover, fruits with brix above 12.3% are considered sufficiently mature for SmartFresh™ treatment allowing fruit to soften after removal from storage.

Ex-store maturity results

Ex-store colour (Table 14)

The average green colour retention of Conference pears from all three orchards stored until June at -1.0°C was better (Minolta green colour -11.2) than pears stored at +1.0°C (Minolta green colour -10.5). Where pears were stored at the higher temperature, treatment with SmartFresh™ reduced the loss of green colour (Minolta green colour -10.7) at 1°C compared to the control (Minolta green colour -9.8).

Ex-store firmness (Table 15)

The overall average ex-store firmness of pears from three orchards stored at +1°C in June (6.6 kg) was not significantly lower than pears stored at -1°C (6.8 kg). However, the rate of softening during subsequent shelf-life was more rapid in fruit stored at the higher temperature (see shelf-life section). In two of the orchards in the study (BG and BE) stored at +1°C, application of full rate SmartFresh™ reduced the rate of softening of fruit (6.8-7.1 kg) compared to untreated fruit (5.9-6.5kg). Ethylene scrubbing was not effective at preventing firmness loss during storage.

Rotting (Table 16)

In all orchards, the incidence of rotting was predominately caused by *Monilinia fructigena* and *Botrytis* to a lesser extent. SmartFresh™ treatments did not affect the incidence of post-harvest losses. Overall, losses between Sept-June in pears stored at -1°C ranged from 2.8-4.2% but increased to 12% when storage was extended until June. In Pears stored at +1°C the incidence of pear rots between September and April ranged from 0.8-2.1% but increased to 23% by the June assessment.

While there was no effect of SmartFresh™ on the incidence of rotting, the addition of ethylene at the point of SmartFresh™ application led to 3.3-8.3% rotting between September and April but led to significant increase in rotting in late stored pears.

% Brix (Table 17)

Soluble solid content of Conference pears was not affected by temperature or SmartFresh™. The % Brix content of fruit ranged from 11.6 to 13.4.

CO₂ injury (Table 18)

The incidence of internal carbon dioxide injury was very sporadic with most instances developing in very late (nine months) in the storage season. However, during shelf-life carbon dioxide injury increased.

Shrivel

In the second year of the trial, the incidence of shrivel was less significant and no treatment effects were observed.

Shelf-Life Results: Softening rates during shelf-life (Annex II Graphs & Table 19)

The description below details the rate of firmness decline of pears stored at -1°C or +1°C and transferred to shelf-life conditions (18°C) after periods of three, six or nine months storage.

The three orchards under study had a similar softening rate during shelf-life in response to temperature during storage and SmartFresh™ treatments.

3 months storage at -1°C: The firmness of untreated fruit dropped from 6 kg to 2 kg after four days at 18°C and were at an eating ripeness of 1.5kg by day six. Pears treated with SmartFresh™ full rate (625 ppb) did not soften during 11 days of shelf-life. Fruit treated with half rate SmartFresh™ remained between 7-6.5 kg for the first four to six days of shelf-life and thereafter firmness dropped to 2 kg by day eleven.

3 months storage at +1°C: Untreated pears and those subject to ethylene scrubbing softened to 2 kg within four days of transfer to 18°C. Pears treated with full and half rate SmartFresh™ failed to soften during shelf-life.

6 months storage at -1°C: Untreated pears stored at -1.0°C softened to 2-2.5kg after four days at 18°C and reached 1.5 kg firmness after five to six days. Pears treated with half rate

SmartFresh™ softened at a more uniform rate reaching an eating quality firmness of 1.5 kg after seven days at 18°C. Full rate SmartFresh™ treated fruit did not soften during shelf-life.

6 months storage at +1°C: The rate of softening of untreated pears stored at the higher temperature reached 1.5kg firmness within five to six days. The rates of softening in half rate treated pears was slower than fruit stored at lower temperatures with little change over the first four days of shelf-life, and reached 2 kg after seven days. Pears treated with full rate SmartFresh™ failed to soften significantly during eight days of shelf-life. Ethylene scrubbed fruit softened at the same rate as untreated fruit.

9 months storage at -1°C: On transfer to shelf-life conditions untreated pears started to soften immediately while fruit treated with half rate SmartFresh™ did not soften during the first three days of shelf-life but then softened rapidly. In each case pears reached a firmness of 3.5-4 kg of firmness in the first four days, attaining an eating quality firmness of 1.5 kg between seven and eight days. Pears treated at full rate SmartFresh™ failed to soften sufficiently over the eight day shelf-life period.

9 months storage at +1°C: Untreated and ethylene scrubbed fruit softened to 1.5 kg within five days of transfer to 18°C. Pears treated with half rate or full rate SF did not soften during the first three days at 18°C however, thereafter half rate treated pears softened rapidly reaching 1.5 kg firmness in seven to eight days. Fruit treated with full-rate SF softened more slowly and uniformly reaching 1.5 kg firmness within eight days.

Ethylene amendments to SmartFresh™ application

The capacity of SmartFresh™ (625 ppb) treated fruit to soften after removal to shelf-life conditions was dependent on the duration of storage. Fruit stored for no more than three months failed to soften; after six months, a degree of softening was initiated but pears failed to reach acceptable eating quality firmness, while after nine months the rate of softening on removal to shelf-life was adequate. The delay/retardation in softening caused by SmartFresh™ in the short-medium term storage period could be mitigated by the application of ethylene at 300, 600 or 900 ppb applied alongside SmartFresh™ in a dose dependent manner. Transfer of fruit to shelf-life after three months storage at +1°C resulted in fruit treated with 900 ppb softening to reach an eating quality firmness of 1.5 kg within seven days while fruit treated with 600 ppb ethylene reached 1.5 kg within 12 days. After six months storage all ethylene/SmartFresh™-treated fruit softened to reach 1.5 kg within seven days, in contrast to pears treated with SmartFresh alone, where fruit never softened sufficiently. After nine months even SmartFresh™-treated fruit softened during shelf-life.

Table 14: Year 2: Ex-store green colour (Minolta - a value, in L, a b mode) of Conference pears stored at two temperatures (0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 ppb and 321 ppb), ethylene scrubbing and a combination of SmartFresh™ (625 ppb) with ethylene

Green colour		Dec	April	June	Dec	April	June	Dec	April	June
		Orchard			Orchard			Orchard		
Treatment	Temperature	BG	BG	BG	BE	BE	BE	LB	LB	LB
	-1.0 to -									
1. Control	0.5°C	-9.5	-10.4	-11.9	-11.2	-10.7	-11.5	-9.1	-7.8	-10.0
	-1.0 to -									
2. SF 312 ppb	0.5°C	-9.6	-9.3	-10.7	-9.7	-11.4	-11.5	-9.0	-10.4	-10.2
	-1.0 to -									
3. SF 625ppb	0.5°C	-12.7	-11.6	-11.5	-11.8	-10.8	-13.1	-7.6	-9.0	-10.5
4. Control	0.5 to 1.0°C	-11.0	-8.0	-10.8	-10.8	-10.7	-10.0	-8.0	-8.8	-8.6
5. SF 312 ppb	0.5 to 1.0°C	-10.7	-8.9	-11.7	-9.8	-10.4	-11.6	-9.8	-9.1	-8.8
6. SF 625ppb	0.5 to 1.0°C	-10.6	-12.1	-11.4	-7.9	-10.5	-11.6	-9.5	-10.0	-9.4
7. Eth scrub	0.5 to 1.0°C	-10.9	-10.2	-11.8	-9.6	-9.2	-10.0	-7.9	-7.2	-10.4
8a.	0.5 to 1.0°C									
SF+900ppb		-10.7	-10.9	-11.0						
8b.	0.5 to 1.0°C									
SF+600ppb		-10.9	-10.9	-11.0						
8c. SF+300ppb	0.5 to 1.0°C	-10.2	-11.0	-11.4						

LSD_{0.05} for the interaction between orchard x treatment x temperature x inspection+ ethylene scrubbing+ ethylene treatments = 2.35 on 52 df

Table 15: Year 2: Ex-store Firmness (N) of Conference pears stored at two temperatures (0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 ppb and 321 ppb), ethylene scrubbing and a combination of SmartFresh™ (625 ppb) with ethylene

Firmness (N)		Dec	April	June	Dec	April	June	Dec	April	June
		Orchard			Orchard			Orchard		
Treatment	Temperature	BG	BG	BG	BE	BE	BE	LB	LB	LB
	-1.0 to -0.5°C									
1. Control	0.5°C	70	71	69	64	66	65	69	67	67
	-1.0 to -0.5°C									
2. SF 312 ppb	0.5°C	72	70	70	69	67	66	69	69	71
	-1.0 to -0.5°C									
3. SF 625 ppb	0.5°C	72	68	70	67	65	65	67	66	68
4. Control	0.5 to 1.0°C	67	63	65	63	55	59	68	63	63
5. SF 312 ppb	0.5 to 1.0°C	69	67	68	67	62	65	67	65	68
6. SF 625 ppb	0.5 to 1.0°C	73	70	71	69	68	67	67	68	66
7. Eth scrub	0.5 to 1.0°C	69	64	65	65	59	55	71	64	62
8a. SF+900 ppb	0.5 to 1.0°C	70	70	67						
8b. SF+600 ppb	0.5 to 1.0°C	74	68	69						
8c. SF+300 ppb	0.5 to 1.0°C	67	71	72						

LSD_{0.05} for the interaction between orchard x treatment x temperature x inspection + ethylene + ethylene treatments = 3.94 on 52 df Divide by firmness values by 9.96 for conversion of Newtons to kg pressure

Table 16: Ex-store % rotting of Conference pears stored at two temperatures (0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 ppb and 321 ppb), ethylene scrubbing and a combination of SmartFresh™ (625 ppb) with ethylene

% Rotting		Dec	April	June	Dec	April	June	Dec	April	June
		Orchard			Orchard			Orchard		
Treatment	Temperature	BG	BG	BG	BE	BE	BE	LB	LB	LB
	-1.0 to -									
1. Control	0.5°C	10	0	10	5	0	20	0	5	15
	-1.0 to -									
2. SF 312 ppb	0.5°C	0	0	10	0	5	10	5	0	10
	-1.0 to -									
3. SF 625ppb	0.5°C	0	0	15	10	10	5	5	5	15
4. Control	0.5 to 1.0°C	0	15	20	0	0	5	5	10	20
5. SF 312 ppb	0.5 to 1.0°C	0	0	15	0	0	20	0	5	25
6. SF 625ppb	0.5 to 1.0°C	0	5	15	5	20	35	5	0	20
7. Eth scrub	0.5 to 1.0°C	0	5	20	0	5	20	0	0	35
8a. SF+900ppb	0.5 to 1.0°C	0	5	25						
8b. SF+600ppb	0.5 to 1.0°C	0	0	55						
8c. SF+300ppb	0.5 to 1.0°C	10	20	60						

LSD_{0.05} for the interaction between orchard x treatment x temperature x inspection = 15.36

LSD_{0.05} for the interaction between treatment x temperature = 5.12

Table 17. Year 2: Ex-store % brix of Conference pears stored at two temperatures (0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 ppb and 321 ppb), ethylene scrubbing and a combination of SmartFresh™ (625 ppb) with ethylene

% Brix		Dec	April	June	Dec	April	June	Dec	April	June
		Orchard			Orchard			Orchard		
Treatment	Temperature	BG	BG	BG	BE	BE	BE	LB	LB	LB
1. Control	-1.0 to 0.5°C	13.0	12.5	12.3	13.1	12.3	12.8	12.9	12.45	12.6
2. SF 312 ppb	-1.0 to 0.5°C	12.7	12.45	12.05	12.9	13.1	12.7	12.7	12.6	12.3
3. SF 625ppb	-1.0 to 0.5°C	12.4	12.5	12.5	13.1	13.1	13.2	13.0	12.85	13.0
4. Control	0.5 to 1.0°C	12.8	11.65	11.8	13.4	13.2	12.4	12.9	12.6	12.3
5. SF 312 ppb	0.5 to 1.0°C	12.9	11.8	12.15	13.2	12.85	12.4	13.2	11.5	12.1
6. SF 625ppb	0.5 to 1.0°C	12.1	11.8	11.75	12.8	12.95	12.8	12.7	12.65	12.7
7. Eth scrub	0.5 to 1.0°C	12.7	12.3	11.95	13.2	12.8	13.0	12.7	12.4	12.3
8a. SF+900ppb	0.5 to 1.0°C	12.3	12.1	11.9						
8b. SF+600ppb	0.5 to 1.0°C	11.9	12.1	11.6						
8c. SF+300ppb	0.5 to 1.0°C	12.5	12.8	11.9						

LSD0.05 for the interaction between orchard x treatment x temperature x inspection= 0.584 on 52 df

Table 18. Year 2: Ex-store % CO₂ injury of Conference pears stored at two temperatures (0.5-1.0°C and -0.5 to -1.0°C) with two rates of SmartFresh™ (625 ppb and 321 ppb), ethylene scrubbing and a combination of SmartFresh™ (625 ppb) with ethylene

% CO ₂ injury		Dec	April	June	Dec	April	June	Dec	April	June
		Orchard			Orchard			Orchard		
Treatment	Temperature	BG	BG	BG	BE	BE	BE	LB	LB	LB
	-1.0 to -									
1. Control	0.5°C	0	0	0	0	0	0	0	0	15
	-1.0 to -									
2. SF 312 ppb	0.5°C	0	0	0	0	0	0	0	0	5
	-1.0 to -									
3. SF 625ppb	0.5°C	0	0	5	0	0	0	0	0	5
4. Control	0.5 to 1.0°C	0	0	0	0	0	0	0	0	0
5. SF 312 ppb	0.5 to 1.0°C	0	0	0	0	0	0	0	0	0
6. SF 625ppb	0.5 to 1.0°C	0	0	5	0	0	0	5	0	5
7. Eth scrub	0.5 to 1.0°C	0	0	0	0	0	0	0	0	5
8a. SF+900ppb	0.5 to 1.0°C	0	0	0						
8b. SF+600ppb	0.5 to 1.0°C	0	0	0						
8c. SF+300ppb	0.5 to 1.0°C	0	0	0						

LSD_{0.05} for the interaction between orchard x treatment x temperature x inspection

Table 19. The number of days taken to reach an eating quality firmness of 15N (1.5 kg) during shelf-life (18°C).

Days to reach		Dec	April	June	Dec	April	June	Dec	April	June
1.5 kg		Orchard			Orchard			Orchard		
Treatment	Temperature	BG	BG	BG	BE	BE	BE	LB	LB	LB
	-1.0 to -									
1. Control	0.5°C	6	6.5	8	6	7	8	6	7	9
	-1.0 to -									
2. SF 312 ppb	0.5°C	-	7	8	-	7	8	-	7	9
	-1.0 to -									
3. SF 625ppb	0.5°C	-	-	-	-	-	-	-	-	-
4. Control	0.5 to 1.0°C	6	7	8	6	7	8	6	7	9
5. SF 312 ppb	0.5 to 1.0°C	-	-	8	-	8	8	-	-	9
6. SF 625ppb	0.5 to 1.0°C	-	-	8	-	-	8	-	-	9
7. Eth scrub	0.5 to 1.0°C	6	7	8	6	7	8	6	7	9
8a. SF+900ppb	0.5 to 1.0°C	10	7	8						
8b. SF+600ppb	0.5 to 1.0°C	11	6.5	8						
8c. SF+300ppb	0.5 to 1.0°C	-	7	8						

Discussion and Conclusions

The results from the second year of the trial were more informative regarding the behaviour of Conference pears under SmartFresh™ treatments. Clearly, in circumstances where pears are removed from store within the first two to three months of treatment then there is a significant delay in fruit softening to acceptable standard, so that it is important to see this treatment as a way of improving the shelf-life behaviour of fruit destined for long-term storage. Storage beyond March at -0.5 – to -1.0°C led to an increase in rotting. There is evidence to suggest that SmartFresh™ has little effect on rot control so the prospect of extending storage life beyond March/April is restricted unless the incidence of rotting can be

reduced, by post-harvest drenching in Rovral. The advantage of using half rate SmartFresh™ is to allow a more even decline in softening during shelf-life.

Raising storage temperature above the accepted -0.5 to -1.0°C has some potential where fruit has been treated with half rate SmartFresh™ within a six month storage window. However, fruit stored at higher temperatures are prone to higher levels of rotting, so the economic benefit of raising the storage temperatures is limited unless disease control is managed effectively.

The application of full rate SmartFresh™ (625 ppb) reduced pears' ability to soften within the first six months of storage. However, where storage was prolonged for nine months, fruits were sufficiently capable of softening on transfer to shelf-life (18°C) conditions. To overcome the lack of ripening initiation in full SmartFresh™-treated fruit, the supplementation of a small dose of ethylene (300-900 ppb) at the time of SmartFresh™-treatment was sufficient to stimulate softening in a dose-dependent manner. As storage progressed, the effect of ethylene induction of ripening was more pronounced when fruit were removed to shelf-life conditions, and by the final inspection (June) 300 ppb of ethylene was as capable as 900 ppb ethylene of stimulating softening.

Knowledge and Technology Transfer

This project was presented at the EMRA Storage Days in March 2012 and 2014.

Appendices

ANNEX I: YEAR 1 SOFTENING PROFILE OF SMARTFRESH-TREATED CONFERENCE PEARS DURING SHELF-LIFE (18°C) DECEMBER 2011

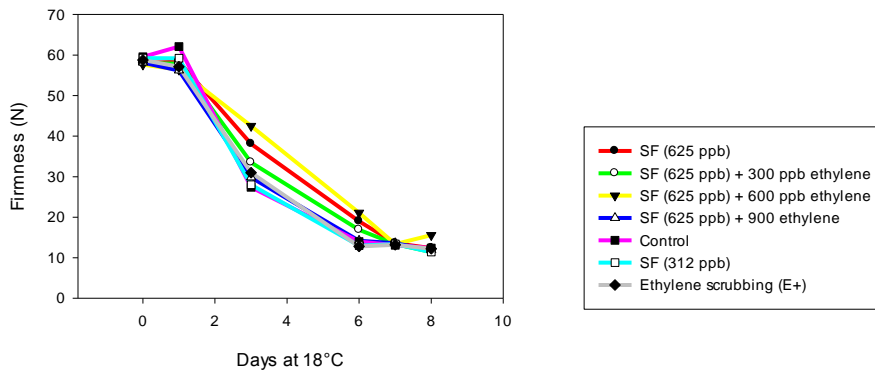


Fig 1.A CA storage of Conference pear (Orchard 39) for 3 months at 1.5-2.0°C

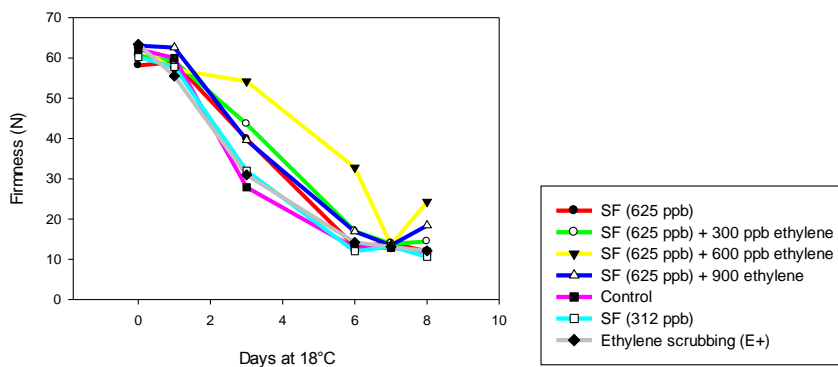


Fig 1.B CA storage of Conference pear (Orchard 39) for 3 months at 0.5-1.0°C

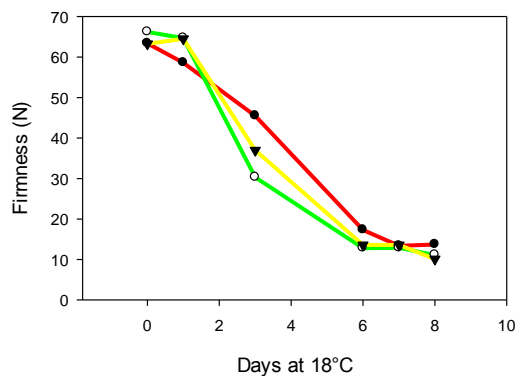


Fig 1.C CA storage of Conference pear (Orchard 39) for 3 months at -0.5 to -1.0°C

Figures 1A-C: Shelf-life softening curves for Conference pear (orchard 39) stored at for 3 months (2% O₂, <1.0% CO₂) either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C

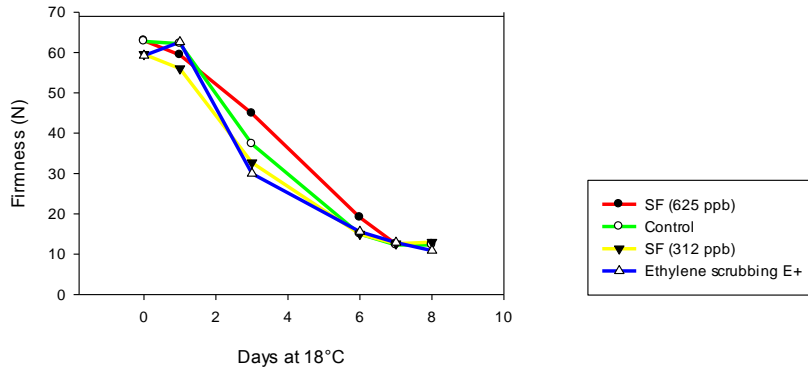


Fig 1.D CA storage of Conference pear (Orchard 40) for 3 months at 1.5-2.0°C

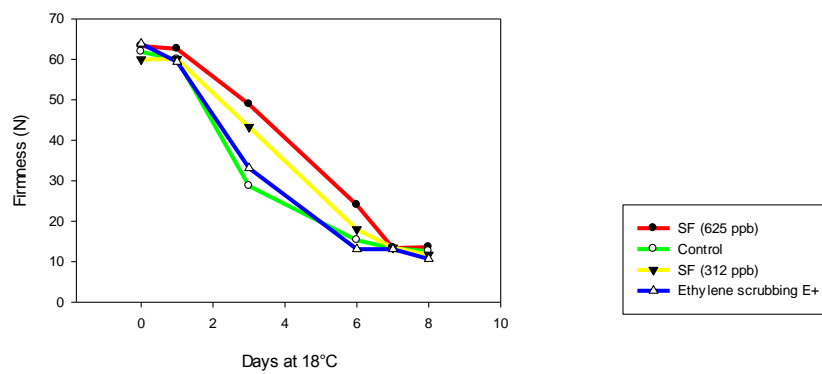


Fig 1.E CA storage of Conference pear (Orchard 40) for 3 months at 1.5-2.0°C

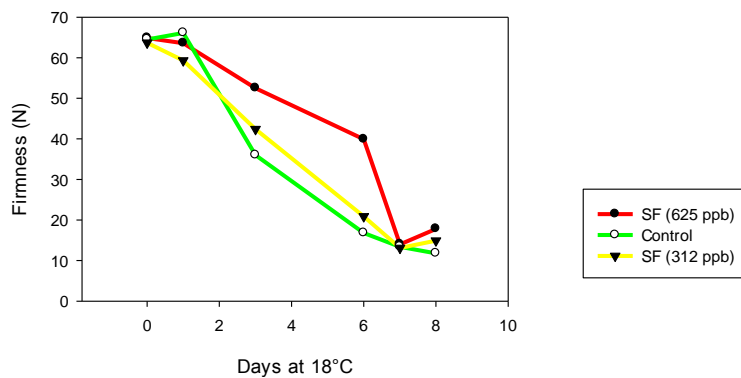


Fig 1.F CA storage of Conference pear (Orchard 40) for 3 months at -0.5 to -1.0°C

Figures 1D-F: Shelf-life softening curves for Conference pear (orchard 40) stored at for 3 months (2% O₂, <1.0% CO₂) either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C

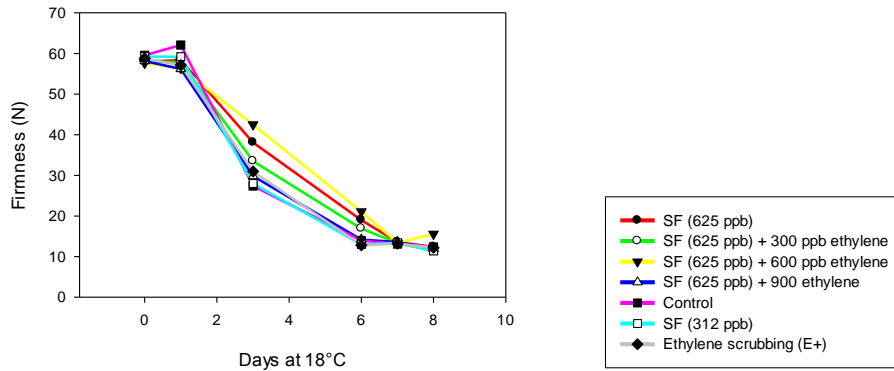


Fig 2.A CA storage of Conference pear (Orchard 39) for 6 months at 0.5-1.0°C

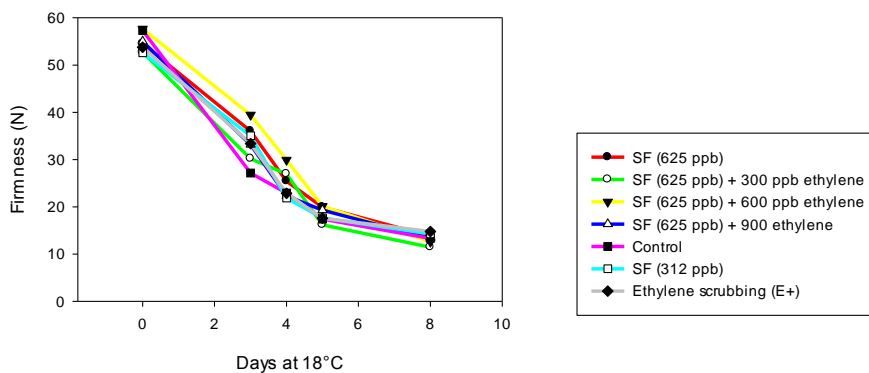


Fig 2.B CA storage of Conference pear (Orchard 39) for 6 months at 0.5-1.0°C

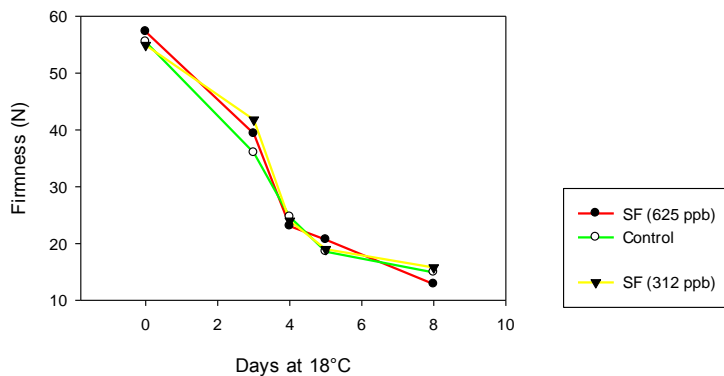


Fig 2.C CA storage of Conference pear (Orchard 39) for 6 months at -0.5 to -1.0°C

Figures 2A-C: Firmness of fruit during 8 days of shelf-life (18°C) for Conference pear (orchard 39) stored for 6 months at 2% O₂, <1.0% CO₂ at either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C.

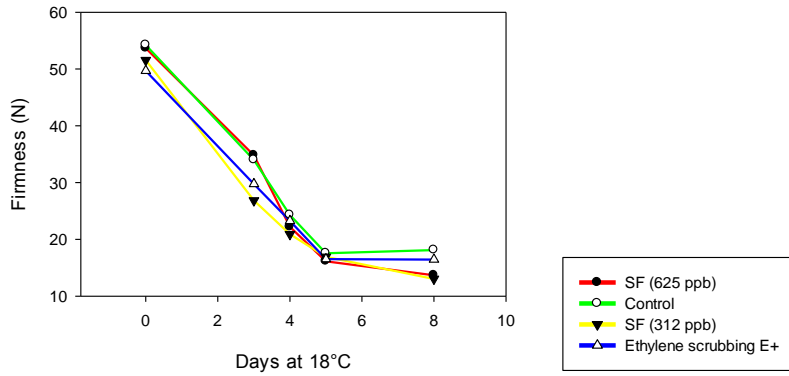


Fig 2.D CA storage of Conference pear (Orchard 40) for 6 months at 0.5-1.0°C

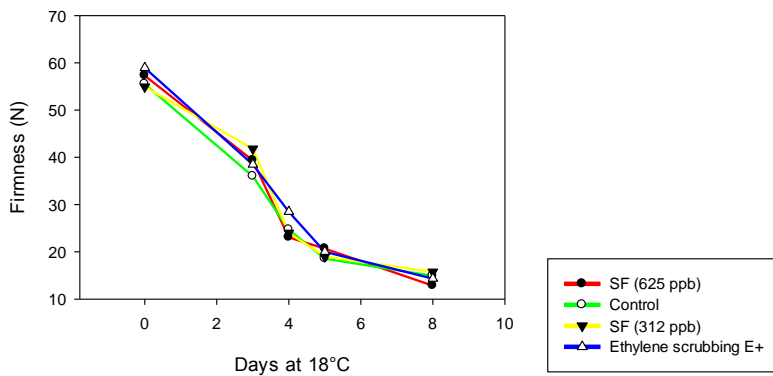


Fig 2.E CA storage of Conference pear (Orchard 40) for 6 months at 0.5-1.0°C

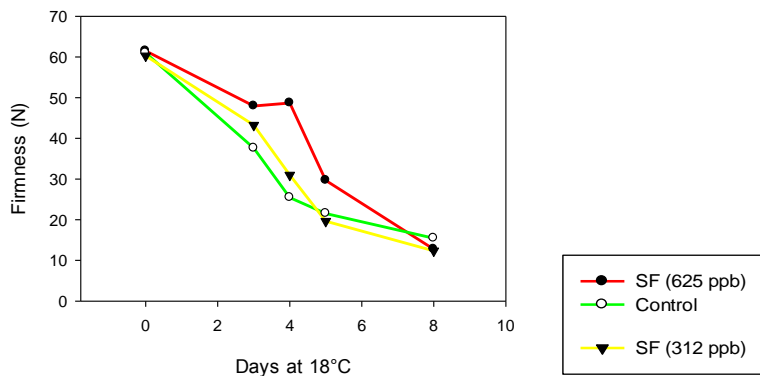


Fig 2.F CA storage of Conference pear (Orchard 40) for 6 months at -0.5 to -1.0°C

Figures 2D-F: Firmness of fruit during 8 days of shelf-life (18°C) for Conference pear (orchard 40) stored for 6 months at 2% O₂, <1.0% CO₂ at either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C.

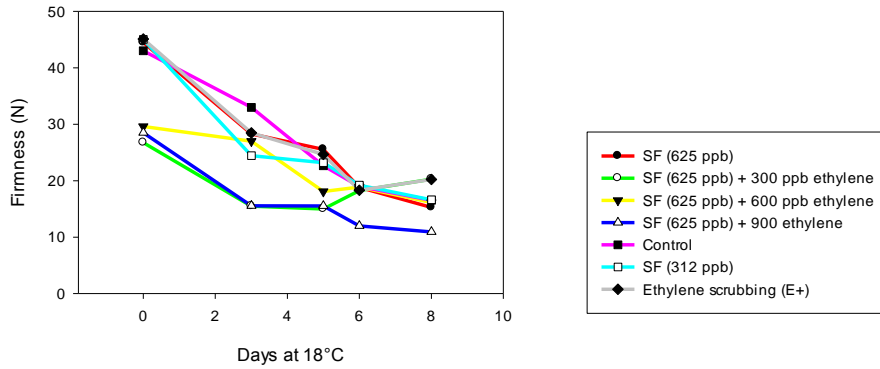


Fig 3.A CA storage of Conference pear (Orchard 39) for 9 months at 1.5-2.0°C

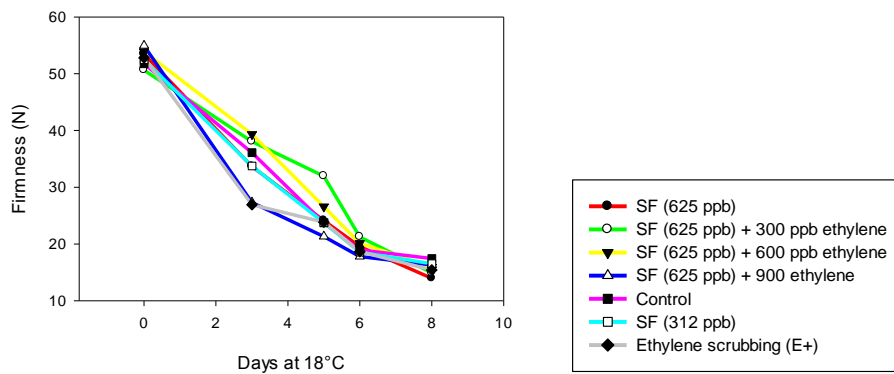


Fig 3.B CA storage of Conference pear (Orchard 39) for 9 months at 0.5-1.0°C

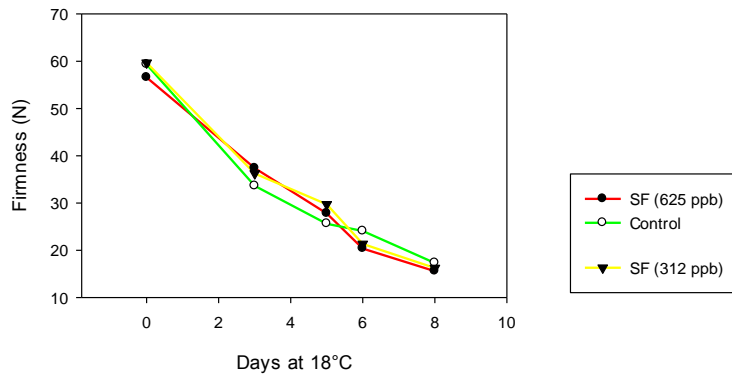


Fig 3.C CA storage of Conference pear (Orchard 39) for 9 months at -0.5 to -1.0°C

Figures 3A-C: Firmness of fruit during 8 days of shelf-life (18°C) for Conference pear (orchard 39) stored for 9 months at 2% O₂, <1.0% CO₂ at either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C.

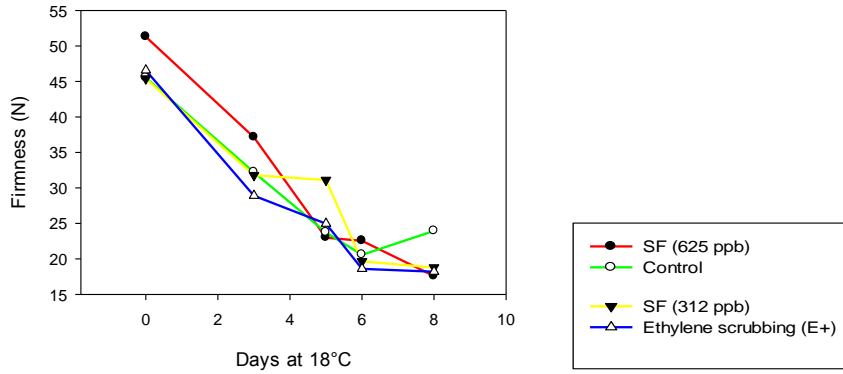


Fig 3.D CA storage of Conference pear (Orchard 40) for 9 months at 1.5-2.0°C

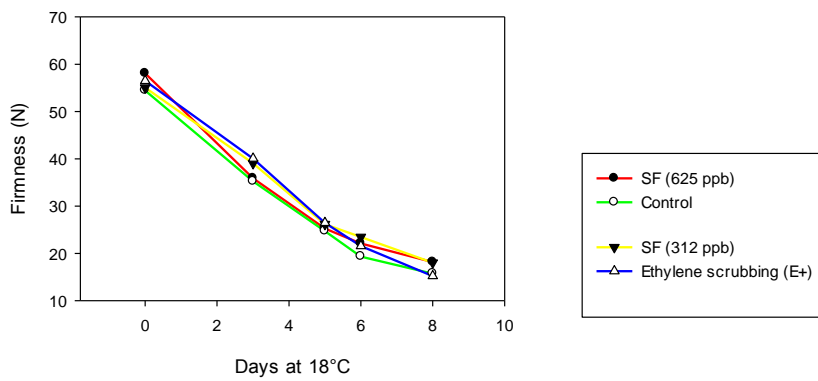


Fig 3.E CA storage of Conference pear (Orchard 40) for 9 months at 0.5-1.0°C

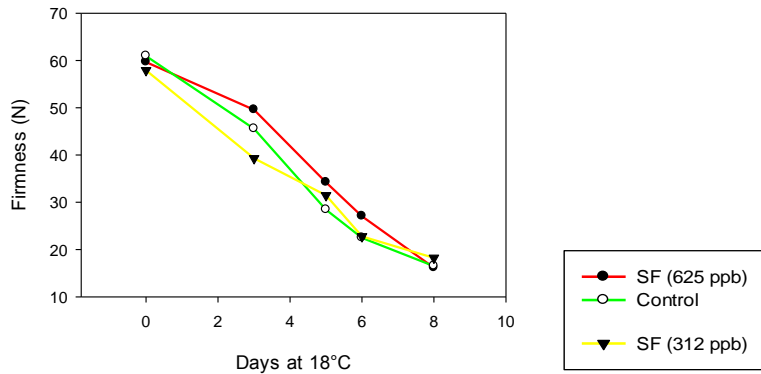
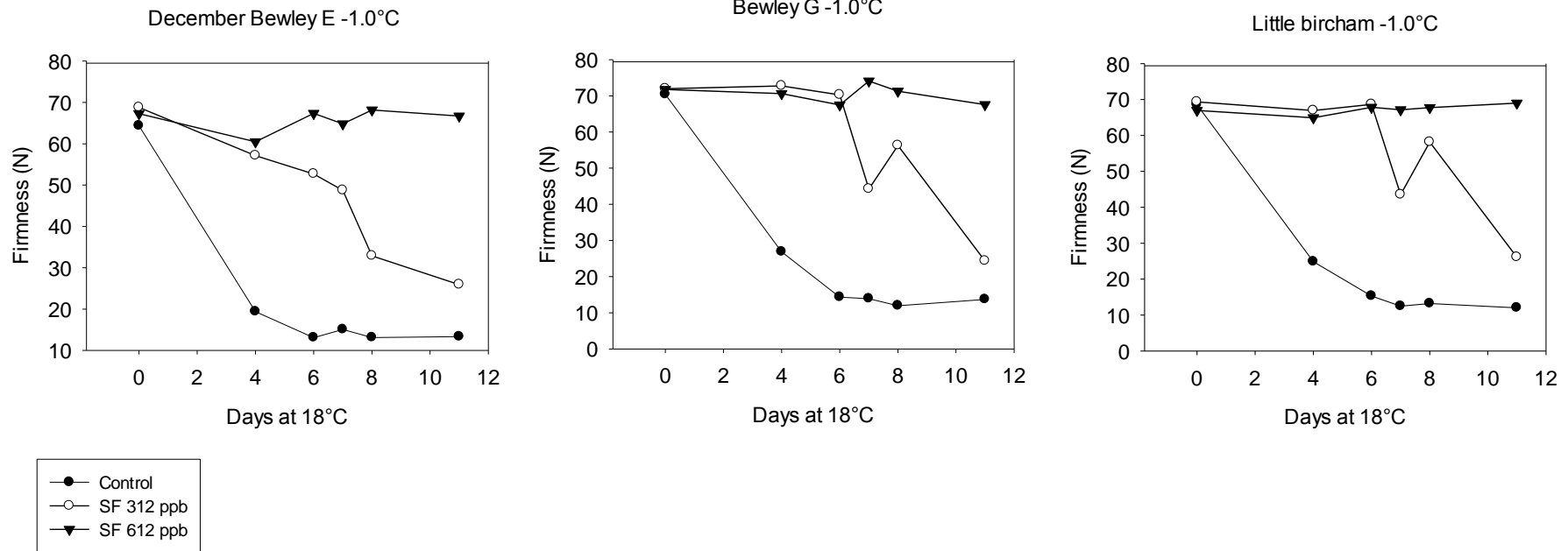


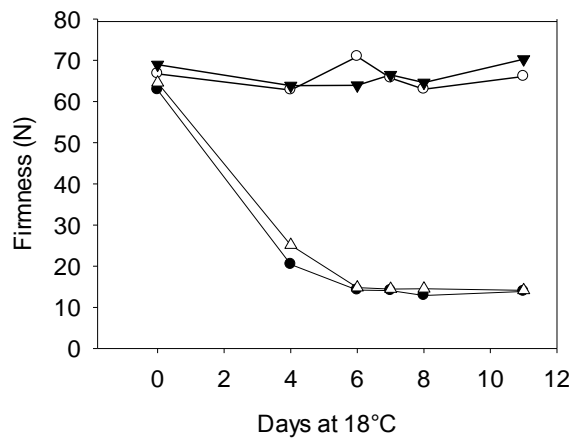
Fig 3.F CA storage of Conference pear (Orchard 40) for 9 months at -0.5 to -1.0°C

Figures 3D-F: Firmness of fruit during 8 days of shelf-life (18°C) for Conference pear (orchard 40) stored for 9 months at 2% O₂, <1.0% CO₂ at either 1.5-2.0°C, 0.5-1.0°C or -0.5 to -1.0°C.

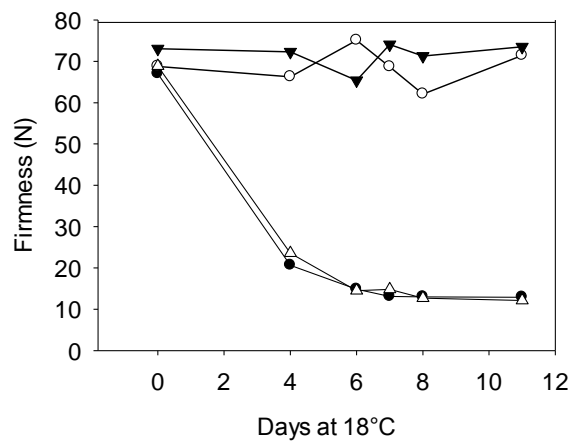
**ANNEX II: YEAR 2 SOFTENING PROFILE OF SMARTFRESH-TREATED CONFERENCE PEARS DURING SHELF-LIFE (18°C)
DECEMBER 2012**



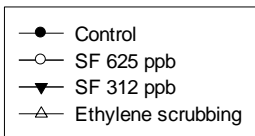
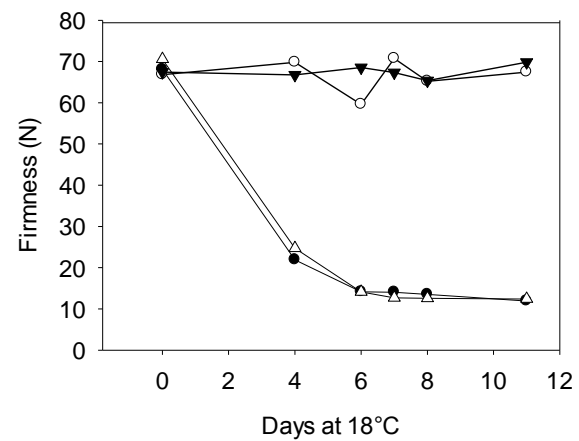
December Bewley E +1.0°C



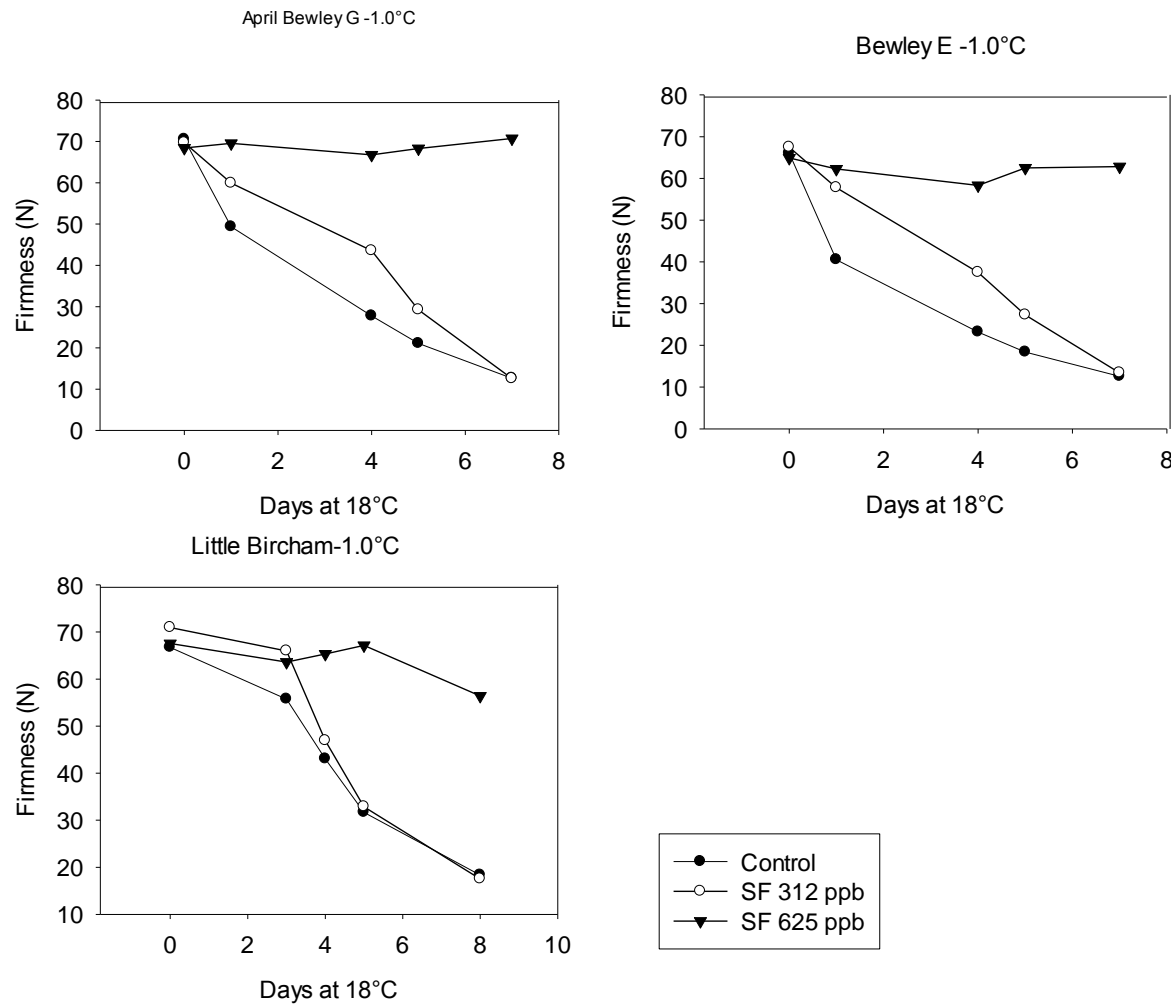
Bewley G +1.0°C



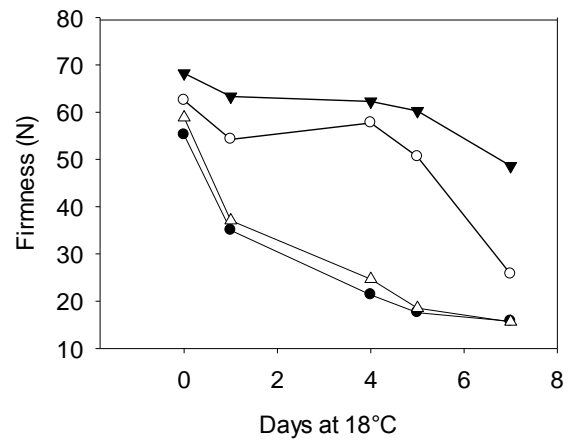
Little Bircham +1.0°C



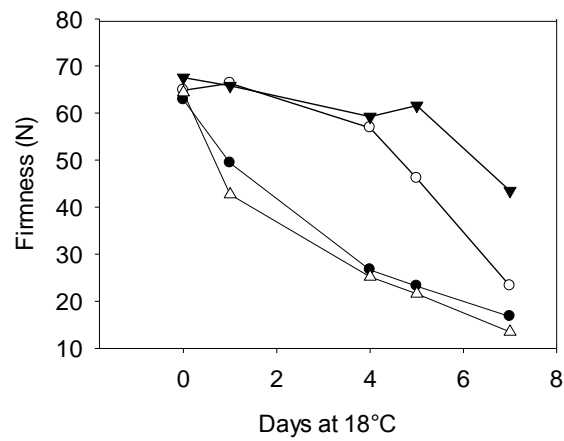
ANNEX IIB SOFTENING PROFILE OF SMARTFRESH-TREATED CONFERENCE PEARS DURING SHELF-LIFE (18°C) April 2013



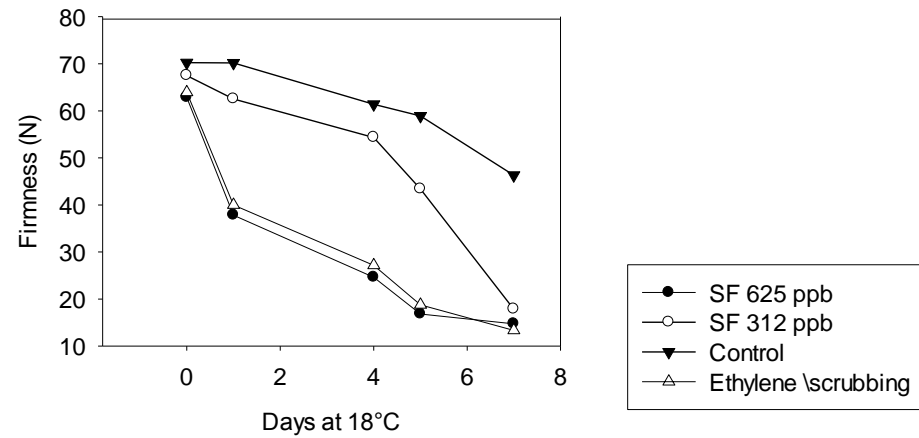
Bewley E +1.0°C



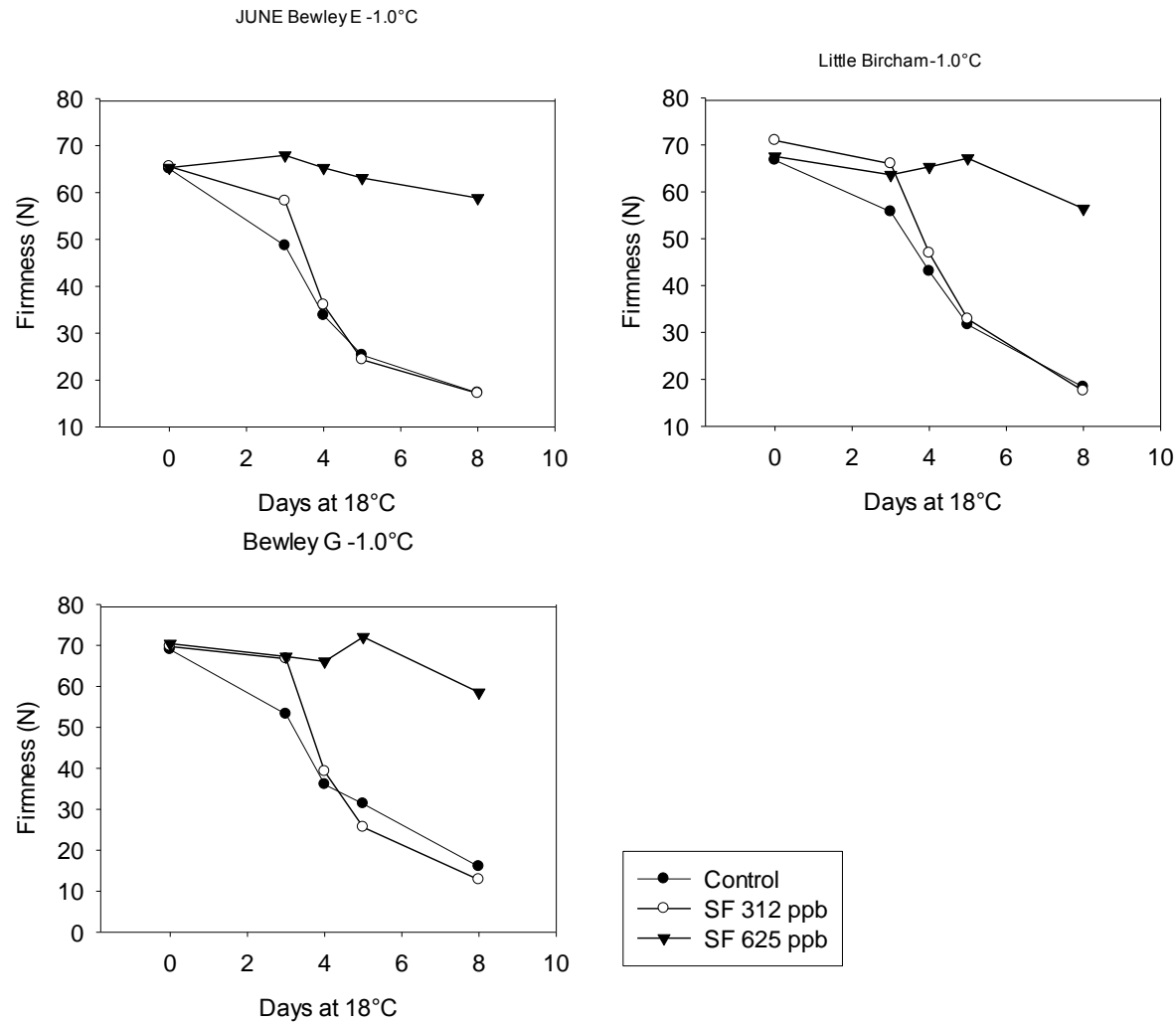
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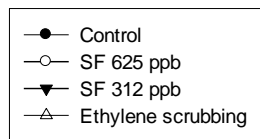
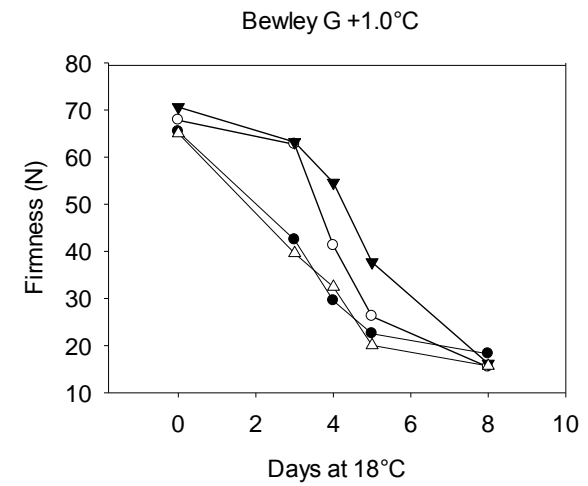
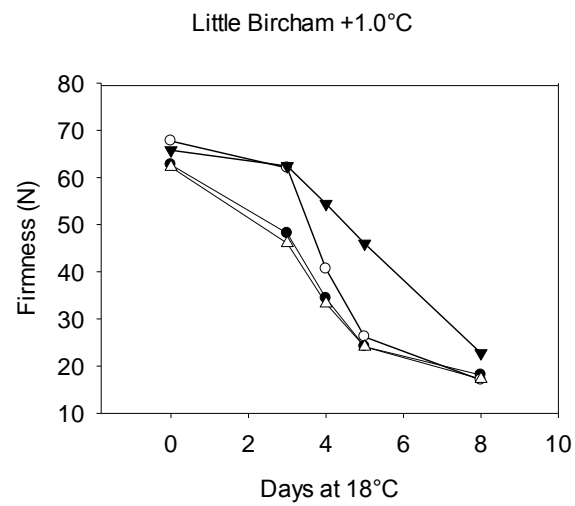
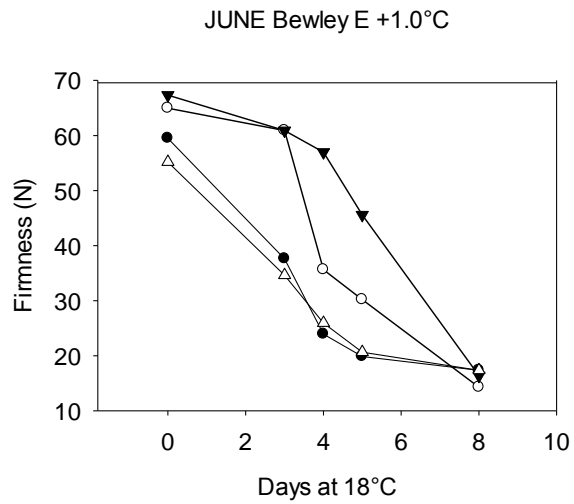


April Bewley G +1.0°C



ANNEX IIC SOFTENING PROFILE OF SMARTFRESH-TREATED CONFERENCE PEARS DURING SHELF-LIFE (18°C) June 2013





ANNEX IID SOFTENING PROFILE OF CONFERENCE PEARS TREATED WITH ETHYLENE AND SMARTFRESH DURING SHELF-LIFE (18°C) AFTER 3 months (December), 6 months (April) and 9 months (June)

