

Storage of Pink Lady

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1. EXECUTIVE SUMMARY

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Project: HR00P08.02

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The objective of this study was to determine the influence of harvest date on fruit quality attributes of Pink Lady apples in storage and thereby establishing the relationship of harvest date to firmness and colour loss, changes in soluble solids content (SSC) and the occurrence of disorders in air or controlled atmosphere (CA) storage. The maturity characteristics and storage behaviour of Pink Lady apples from Hawkes Bay (Orchards 1, 2 and 3) and Nelson district (Orchards 4, 5 and 6) were evaluated on fruit harvested weekly on 5 occasions (designated H1, H2, H3, H4 and H5) over the period of April 3 to May 1, and stored in air and CA at 0.5°C.

The main findings were:

- Over the 5 harvests, SPI and colour measured with a Braeburn colour cards (units) or hue angle (°h), changed markedly: SPI increased from 0.9 in the H1 to 3.7 in H5. Background colour increased from 3.6 in H1 to 5.6 units in H5. The hue angle (°h) was similar in H1 and H2 averaging 113.1°, but decreased between H2 and H5 from 113.1 to 105.8 °h.
- Firmness decreased from 9.6 kgf in the H1 to 8.4 kgf in H5 and internal ethylene concentration (IEC) was at low levels ($\leq 0.2 \mu\text{l L}^{-1}$) in all orchards and all harvests. There was a trend for SSC to increase slightly with later harvests, from 12.6% in the H1 to 13.5% in the H5.
- Blush coverage (%) was greater than 40% in all orchards at all harvests. Fruit weight increased from 143.0g in the H1 to 165.8g in H5.
- Firmness (kgf) was lower during storage with advancing harvest date and increasing storage duration. After 6 weeks of air storage, fruit from H1 were approximately 1.0 kgf firmer compared to fruit from H5.
- Firmness after 18 weeks of air storage was approximately 6.7 kgf.
- After 18 weeks of CA storage, firmness of fruit from H1 and H2 was approximately 8.9 kgf, and approximately 7.7 kgf for fruit from H3, H4 and H5.
- After 18 weeks of CA storage, fruit had a firmness of 8.5 kgf and ranging from 1.5 to 2.2 kgf firmer compared to fruit stored in air.
- After shelf life (7 days at 20°C) following 12 and 18 weeks of air storage, firmness was 6.9 kgf and 6.6 kgf, respectively.
- After shelf life at 20°C following 12 or 18 weeks of CA storage, fruit were from 1.6 to 2.1 kgf firmer compared to fruit that had been stored in air.
- After 18 weeks of air storage, background colour of fruit from H1 and H2 were approximately 5.5 units and fruit from H3, H4 and H5 were approximately 6.4 units. Fruit from H1 and H2 had approximately 5° higher hue angle compared to H3, H4 and H5 after 18 weeks of air storage.

- After 18 weeks CA storage, background colour of fruit from H1 and H2 were an average of approximately 4.6 units compared to 5.6 units in H3, H4 and H5. Fruit from harvests 1 and 2 had approximately 6° higher °h compared to H3, H4 and H5 after 18 weeks of CA storage.
- After shelf life at 20°C following 12 and 18 weeks of air storage, background colour was approximately 0.5 units lower (more green), and 4° hue angle higher in harvests 1 and 2 compared to H3, H4 and H5.
- After shelf life at 20°C following 12 and 18 weeks of CA storage, background colour was approximately 1.0 unit lower (more green), and 6° hue angle higher in H1 and H2 compared to H3, H4 and H5.
- SSC generally increased during storage in fruit from all orchards and harvest dates. In H1, H2, and H3, the increase in SSC (%) during storage was approximately 1.2%. In H4 and H5, SSC increased by approximately 0.8% during storage. Fruit stored in CA had approximately 0.5% higher SSC compared to fruit stored in air.
- After 18 weeks of storage, there was an internal browning incidence (%) ranging from 1 to 31% in fruit from orchards 4, 5 and 6. Internal browning occurred at similar levels in fruit stored in CA and air.
- Superficial scald did not occur in fruit stored in CA from any of the harvests or orchards. In air storage, superficial scald occurred after 12 and 18 weeks of storage with incidence ranging on average from 0 to 73%. There was a trend for superficial scald to be lower with later harvest decreasing on average from 63% in H1 to 2.5% in H5.
- There was no greasiness in fruit stored in CA. Greasiness incidence (%) and severity increased with later harvest date and storage duration in air ranging from 2 to 44%. There was also a trend for greasiness to occur earlier in storage with later harvest date.

It is concluded that:

- Pink Lady apples stored in air at 0.5°C for greater than approximately 12 weeks are unlikely to be greater than 6.5 kgf firmness irrespective of harvest date.
- Fruit stored greater than 6 weeks in air at 0.5°C is unlikely to retain a “lime green” background colour irrespective of harvest date.
- Fruit from H1 and H2 but not H3, H4 and H5 are likely to retain “lime” green background colour during storage and shelf life at 20°C for up to 18 weeks of CA, or 12 weeks of air storage.
- Overall, considering firmness, green background colour, and the occurrence of disorders in storage, the optimum date for Pink Lady would be approximately the last week of March to the start of April depending upon the orchard.
- Current harvest parameters (ESP specifications) are not appropriate for Pink Lady. A specification of an SPI of 0.5-1.0 at harvest is likely to be appropriate, since at this SPI all fruit in this study had minimum blush coverage of 40% and SSC of 12%.
- Fruit from all orchards harvested at approximately 12% SSC attained greater than 13.0% SSC after storage.
- CA storage established within 7 days of harvest is recommended for Pink Lady to increase firmness and background colour retention and to reduce the risk of storage disorders in particular greasiness. An atmosphere of 2% O₂:2% CO₂ is likely to be appropriate.

- CA may not be a causative factor in internal browning in Pink Lady.
- The data in this study indicate that measures to control superficial scald occurrence in Pink Lady are necessary. The current practice of drenching fruit at harvest with diphenylamine (DPA) at 300ppm is likely to provide satisfactory control of superficial scald for up to 16 weeks of storage.

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2. INTRODUCTION

Pink Lady is a mid to late season cultivar that is relatively new to the New Zealand pipfruit industry. Current postharvest practises are based largely on the practises of Australia and other overseas industries. There is little information on the optimum harvest maturity or on the storage requirements of New Zealand grown Pink Lady to ensure successful export to Europe and the United Kingdom (UK).

The optimum harvest maturity for Pink Lady is an important issue for successful export and marketing to the UK and Europe. Pink Lady is required to have “red blush” (but not bold red) on more than 40% of the fruit surface area and a “lime” green background colour. Generally, blush area increases the longer fruit remain on the tree but storage potential declines and other quality attributes such as firmness and background colour may be lost in storage. Consequently, if harvest is delayed in order to achieve adequate blush coverage then fruit may be more mature and more likely to lose green background colour during storage. Similarly, fruit may not retain adequate firmness retention in storage to meet the market minimum out-turn requirement of 6.5 kgf. Conversely, fruit harvested too immature may not attain the soluble solids content (SSC) of 13% that is required in the market, immature fruit may also be more prone to develop superficial scald in storage. In contrast, over-mature fruit are more likely to develop greasiness and/or internal browning during storage.

Although the use of controlled atmosphere (CA) storage for extending the storage life of apples is common, the benefits of CA storage in comparison to air storage have not been assessed for Pink Lady grown in New Zealand. In CA of apples, low O₂ at levels of 1-3% with CO₂ at levels of 1-3% are typically used to increase the retention of fruit quality attributes such as firmness and background colour during storage, and can reduce some storage disorders such as bitter pit and superficial scald. The most commonly used atmosphere in New Zealand is 2% O₂ : 2% CO₂. Although apples are generally tolerant to O₂ and CO₂ concentrations in this range, injury can occur either as browning of the skin and/or flesh (Burmeister and Dilley, 1995; Elgar et. al, 1998). Internal browning has occurred in New Zealand grown Pink Lady during storage, but it has not been established whether use of CA increases the risk of its occurrence.

The objective of this study was to determine the influence of harvest date on fruit quality attributes of Pink Lady apples in storage and thereby establishing the relationship of harvest date to firmness and colour loss, changes in soluble solids content (SSC) and the occurrence of disorders in air or controlled atmosphere (CA) storage. The maturity characteristics and storage behaviour of Pink Lady apples from Hawkes Bay (Orchards 1, 2 and 3) and Nelson district (Orchards 4, 5 and 6) were evaluated on fruit harvested weekly on 5 occasions over the period of April 3 to May 1, and stored in air and CA at 0.5°C.

3. MATERIALS AND METHODS

3.1 FRUIT

Fruit were harvested from 3 orchards (Orchards 1,2, and 3) in the Hawkes Bay district and 3 orchards (Orchards 4, 5, and 6) in the Nelson district) on 5 occasions (designated H1, H2, H3, H4 and H5) during the harvest season beginning the 2nd of April. Between districts the dates for each harvest occasion were within 1 to 3 days of each other. Fruit were harvested to an approximate count size of 120 and a minimum of 40% pink-red blush coverage and packed into commercial packaging. Fruit were then transported to HortResearch, Mt. Albert by overnight courier and allocated to treatments.

Some details specific to each orchard are as follows. Orchards 1, 2 and 3 were 7, 8 and 6 years old, respectively, and orchards 4, 5 and 6 were 5 years old. Orchards 1, 2 and 4 were on Mark rootstock. Orchard 3 was on M106, orchard 5 was on M26 and Orchard 6 was on M793 rootstock. Orchards 1 and 3 had been root-pruned and orchards 2, 4 and 5 had reflective mulch applied.

3.2 CA STORAGE

CA storage was conducted in tents constructed of high density polyethylene plastic (Permethane Ltd., Auckland, NZ), and the atmosphere was established within 3 days of harvest. The CA tents were initially ventilated with N₂ at a flow rate of 5-10 L min⁻¹ until 5% O₂ was reached (approximately 4-6 h), then ventilated with an atmosphere of 2% O₂ : 2% CO₂ at 0.2 L min⁻¹. The atmosphere within the tent was monitored with a portable gas analyser and the atmosphere maintained within ±0.2% of the required levels.

3.3 FRUIT ASSESSMENTS

Fruit were assessed for internal ethylene (IEC), flesh firmness (FF) background colour (BC), soluble solids content (SSC), starch pattern index (SPI) and titratable acidity (TA). Internal ethylene was measured by withdrawing a 1 cm³ sample of gas from the core of each fruit and analysing the sample by flame ionisation gas chromatography (Hewlett Packard 5890 series II, fitted with a glass Alumina column). Flesh firmness was determined on pared surfaces on opposite sides of each fruit once the fruit had been equilibrated at 20°C using an Effegi penetrometer with a 7/16 inch head mounted on a hand-operated drill stand. Background skin colour was determined by comparing fruit against the ENZA 'series Braeburn colour cards. In addition, Royal Gala colour cards 4 and 5 were used and given the designation 4.5 and 5.5, respectively within the Braeburn series. Soluble solids concentration (°brix) was determined with a digital Atago refractometer on the juice expressed during firmness measurement. The degree of starch breakdown was determined by dipping the cut half of each fruit into an iodine solution for 30 seconds and comparing the resulting pattern with the 1998 ENZA starch pattern index (SPI) for apples. For titratable acidity (TA) approximately 10g of frozen fruit flesh was macerated and mixed with 25 ml water and titrated with 0.1mol/L sodium hydroxide to pH 8.2 (716 DMS titrator, Metrohm, Switzerland). Results were expressed as a percentage (%) titratable acidity (malic acid equivalent).

Minolta CR300 Chroma Meter was used to measure the hue angle (°h) and the 'a' value on the green portion of the fruit skin. Hue angle is a measure of colour that quantifies that the change from green to yellow in degrees (°). A decreasing °h indicates the fruit skin colour is changing from green to yellow. The 'a' value is a measure of the amount of green to red colour. The more negative the 'a' value, the greater the green colour of the fruit skin.

Greasiness was rated on a scale of 0 to 3 with 0= no greasiness (fruit were dry to the touch) ; 1= slight greasiness (fruit tacky to the touch) ; 2= fruit surface slippery to the touch; 3=very slippery to the touch (oily).

Superficial scald was rated on a scale of 0 to 3 with 0 = no scald; 1=<25% cover of the fruit surface covered; 2= between 25-50% cover and 3= >50% of the fruit surface.

Internal disorders were assessed by transversely cutting fruit several times and inspecting for symptoms. Severity of internal browning was noted by estimating the surface area of the cut surface at the equator affected with internal browning: 0 to 5. 0= no browning; 1= <5%; 2= 5-25%; 3= 25-50%; 4= 50-75% and 5= >75%.

4. RESULTS

4.1 MATURITY

Of the maturity characteristics measured, SPI, and background colour measured with the Braeburn colour cards or as hue angle ($^{\circ}$ h), changed the most rapidly between harvests (Fig. 1). SPI increased from 0.9 in H1 to 3.7 in H5. With respect to SPI, fruit from the Hawkes Bay district (orchards 1-3) were more advanced compared to fruit from the Nelson district (orchards 4-6). The rate of increase in SPI in orchards 4,5 and 6 appeared to decrease after H3.

Background colour measured with the Braeburn cards increased from of 3.6 units in the H1 to 5.6 units in H5. The hue angle was similar in H1 and H2 averaging 113.1° . The skin colour decreased at a more rapid rate between the H2 and H5 from an average of 113.1° to 105.8° hue angle. The 'a' value followed a similar pattern as the $^{\circ}$ hue angle, decreasing from an average of -19.1 in H1 to -12.8 in H5 (Tables 1-5).

Firmness of fruit from all orchards decreased from an average of 9.6 kgf in H1 to 8.4 kgf in the H5. There was a trend for SSC (%) to increase with later harvest ranging from 12.5% to 15.1% between orchards in H5. Orchards 4, 5 and 6 tended to have higher SSC compared to orchards 1,2 and 3. IEC was relatively low in all orchards and did not increase with advancing harvest (Fig. 1) and the average fruit weight of the sample generally increased from 143g in H1 to 165.8g in H5 (Tables 1-5). Blush (%) was greater than the minimum 40% in all orchards and at all harvests.

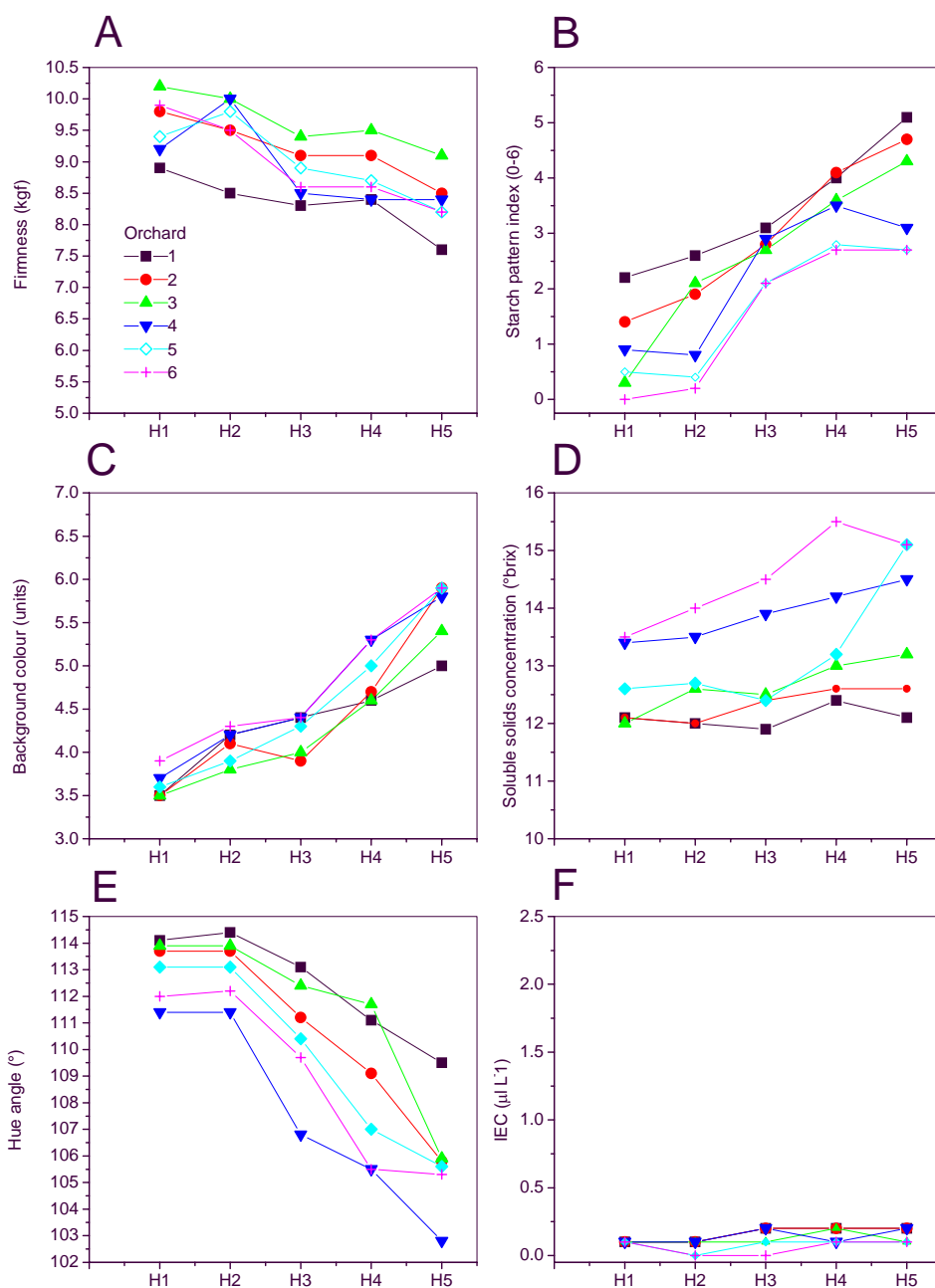


Figure 1. The relationship between harvest date and firmness (A), starch pattern index (B), background colour (C), soluble solids content (D), hue angle (E), and internal ethylene concentration (F) on maturity characteristics of Pink Lady apples harvested at weekly intervals on 5 occasions from Hawkes Bay orchards (orchards 1-3) and Nelson orchards (orchards 4-6). Values are the average of 20 fruit.

Table 1. Fruit characteristics of Pink Lady apples harvested from Hawkes Bay orchards (Orchards 1, 2 and 3) on the 4th April or from the Nelson district (Orchards 4, 5 and 6) on the 2nd of April, 2001. Values are the average of 20 fruit.

Fruit characteristics	Orchard						<i>Average</i>
	1	2	3	4	5	6	
FF (kgf) Harvest	8.9	9.8	10.2	9.2	9.4	9.9	9.6
SPI	2.2	1.4	0.3	0.9	0.5	0.0	0.9
BC	3.5	3.5	3.5	3.7	3.6	3.9	3.6
Hue angle (°h)	114.4	113.7	113.9	111.4	113.1	112.0	113.1
IEC ($\mu\text{L L}^{-1}$)	0.1	0.1	0.1	0.1	0.1	0.1	0.1
'a' value	-20.7	-19.5	-19.7	-17.3	-19.3	-18.0	-19.1
Blush (%)	55.8	70.8	55.8	62.3	63.0	57.5	60.8
SSC (%)	12.1	12.1	12.0	13.4	12.6	13.5	12.6
TA (%)	0.64	0.65	0.62	0.65	0.58	0.67	0.63
Fruit weight (g)	139.6	147.9	132.6	150.4	138.7	149.1	143.0

Table 2. Fruit characteristics of Pink Lady apples harvested from Hawkes Bay orchards (Orchards 1, 2 and 3) on, 11th April or from the Nelson district (Orchards 4, 5 and 6) on 9th April, 2001. Values are the average of 20 fruit.

Fruit characteristics	Orchard						<i>Average</i>
	1	2	3	4	5	6	
FF (kgf) Harvest	8.5	9.5	10.0	10.0	9.8	9.5	9.5
SPI	2.6	1.9	2.1	0.8	0.4	0.2	1.3
BC	4.2	4.1	3.8	4.2	3.9	4.3	4.1
Hue angle (°h)	114.4	113.7	113.9	111.4	113.1	112.2	113.1
IEC ($\mu\text{L L}^{-1}$)	0.1	0.1	0.1	0.1	0.0	0.0	0.1
'a' value	-20.7	-19.5	-19.7	-17.3	-19.3	-18.2	-19.1
Blush (%)	55.5	73.0	64.5	74.3	62.0	58.0	64.5
SSC (%)	12.0	12.0	12.6	13.5	12.7	14.0	12.8
TA (%)	0.61	0.59	0.60	0.58	0.62	0.70	0.62
Fruit weight (g)	139.4	140.1	137.3	147.8	158.3	142.5	144.2

Table 3. Fruit characteristics of Pink Lady apples harvested from Hawkes Bay orchards (Orchards 1, 2 and 3) on, 18th April or from the Nelson district (Orchards 4, 5 and 6) on 17th April, 2001. Values are the average of 20 fruit.

Fruit characteristics	Orchard						<i>Average</i>
	1	2	3	4	5	6	
FF (kgf) Harvest	8.3	9.1	9.4	8.5	8.9	8.6	8.8
SPI	3.1	2.8	2.7	2.9	2.1	2.1	2.6
BC	4.4	3.9	4.0	4.4	4.3	4.4	4.2
Hue angle (°h)	113.1	111.2	112.4	106.8	110.4	109.7	110.6
IEC ($\mu\text{l L}^{-1}$)	0.2	0.2	0.1	0.2	0.1	0.0	0.1
'a' value	-19.1	-17.6	-18.9	-13.8	-16.7	-15.8	-17.0
Blush (%)	60.0	72.0	65.5	77.0	72.5	70.5	69.6
SSC (%)	11.9	12.4	12.5	13.9	12.4	14.5	12.9
TA (%)	0.57	0.59	0.57	0.60	0.61	0.52	0.58
Fruit weight (g)	154.7	151.0	145.1	157.9	158.6	150.0	152.9

Table 4. Fruit characteristics of Pink Lady apples harvested from Hawkes Bay orchards (Orchards 1, 2 and 3) on 26th April or from the Nelson district (Orchards 4, 5 and 6) on 23th April, 2001. Values are the average of 20 fruit.

Fruit characteristics	Orchard						<i>Average</i>
	1	2	3	4	5	6	
FF (kgf) Harvest	8.4	9.1	9.5	8.4	8.7	8.6	8.8
SPI	4.0	4.1	3.6	3.5	2.8	2.7	3.4
BC	4.6	4.7	4.6	5.3	5.0	5.3	4.9
Hue angle (°h)	111.1	109.1	111.7	105.5	107.0	105.5	108.3
IEC ($\mu\text{l L}^{-1}$)	0.2	0.2	0.2	0.1	0.1	0.1	0.1
'a' value	-17.2	-15.4	-17.9	-13.0	-13.4	-12.5	-14.9
Blush (%)	62.5	69.8	65.0	78.5	81.0	72.0	71.5
SSC (%)	12.4	12.6	13.0	14.2	13.2	15.5	13.5
TA (%)	0.58	0.57	0.59	0.54	0.62	0.71	0.60
Fruit weight (g)	151.5	158.0	154.5	177.4	162.0	149.6	158.8

Table 5. Fruit characteristics of Pink Lady apples harvested from Hawkes Bay orchards (Orchards 1, 2 and 3) on 2nd May or from the Nelson district (Orchards 4, 5 and 6) on 30th April, 2001. Values are the average of 20 fruit.

Fruit characteristics	Orchard						<i>Average</i>
	1	2	3	4	5	6	
FF (kgf) Harvest	7.6	8.5	9.1	8.4	8.5	8.2	8.4
SPI	5.1	4.7	4.3	3.1	2.6	2.7	3.7
BC	5.0	5.9	5.4	5.8	5.7	5.9	5.6
Hue angle (°h)	109.5	105.8	105.9	102.8	105.6	105.3	105.8
IEC ($\mu\text{L L}^{-1}$)	0.2	0.2	0.1	0.2	0.1	0.1	0.1
'a' value	-15.6	-12.3	-13.2	-10.8	-12.3	-12.4	-12.8
Blush (%)	71.0	83.0	73.0	82.5	85.5	76.0	78.5
SSC (%)	12.1	12.6	13.2	14.5	13.5	15.1	13.5
TA (%)	0.57	0.58	0.57	0.54	0.65	0.70	0.60
Fruit weight (g)	153.6	167.0	148.6	181.6	173.2	170.9	165.8

4.2 FIRMNESS

Firmness during storage was lower with advancing harvest date and increasing storage duration (Fig. 1). On average, after 18 weeks of air storage, firmness decreased from an average of 9.0 kgf at harvest to of approximately 6.7 kgf. Fruit stored in CA had an average of 8.5 kgf firmness across all harvests, and ranging from 1.5 to 2.2 kgf firmer compared to air-stored fruit after 18 weeks storage.

After shelf life following 12 or 18 weeks of air storage, fruit firmness was 6.9 and 6.6 kgf, respectively (Fig. 3). Fruit that had been stored in CA ranged from 1.6 to 2.1 kgf firmer after shelf life at 20°C following 12 and 18 weeks of CA storage compared to fruit that had been stored in air.

The largest variation in firmness was between individual orchards both during storage and after shelf life (Figs 4 and 5, respectively). In general orchards with firmer fruit at harvest also had firmer fruit relative to the other orchards during storage.

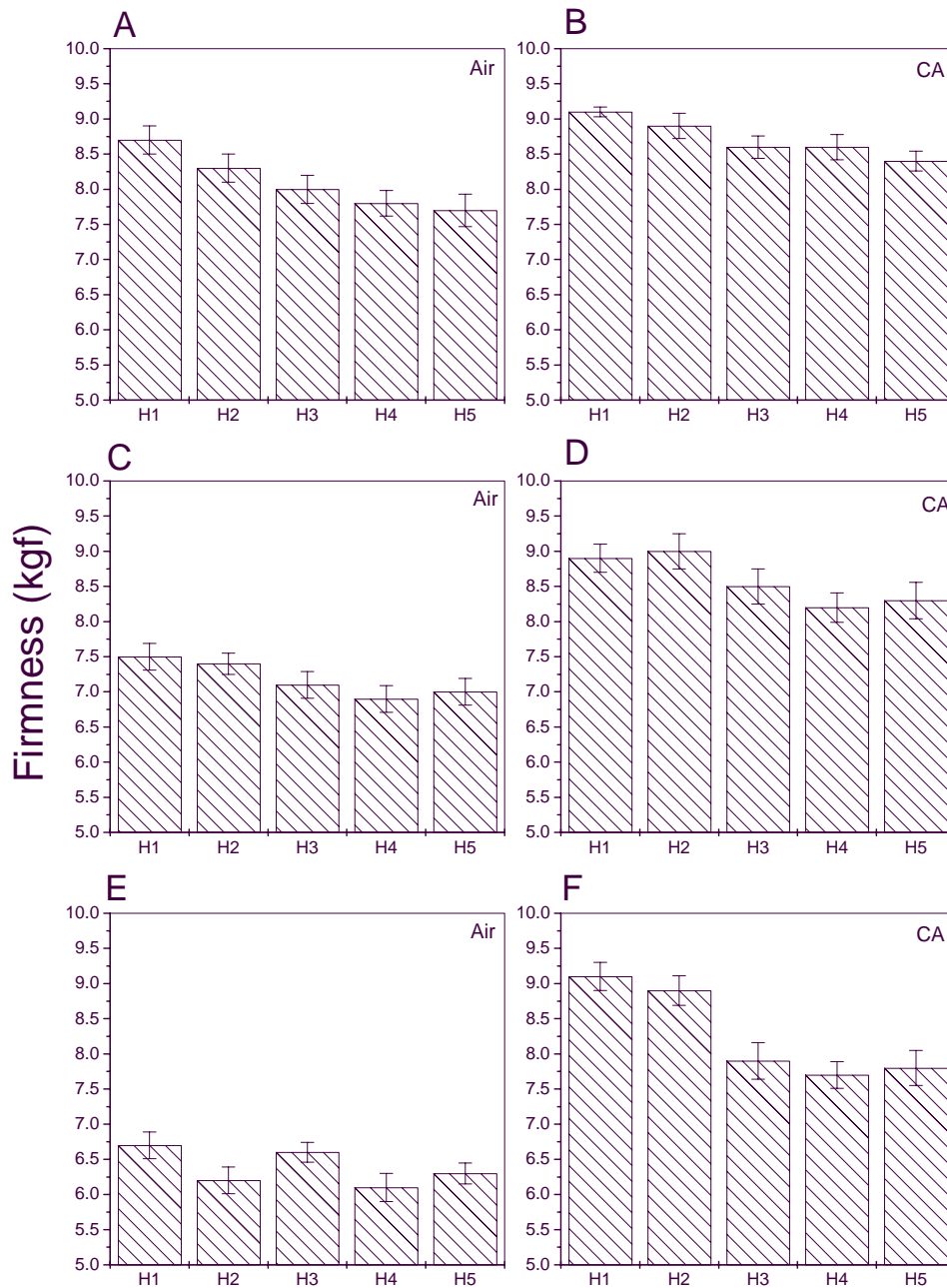


Figure 2. Fruit firmness after 6 (A, B), 12 (C, D) and 18 (E, F) weeks of air (A, C, E) or CA (B, D, F) storage of Pink Lady apples harvested at weekly intervals on 5 occasions (H1, H2, H3, H4 and H5). Values are the average 6 orchards of 10 fruit each \pm standard error of the mean (S.E.M.).

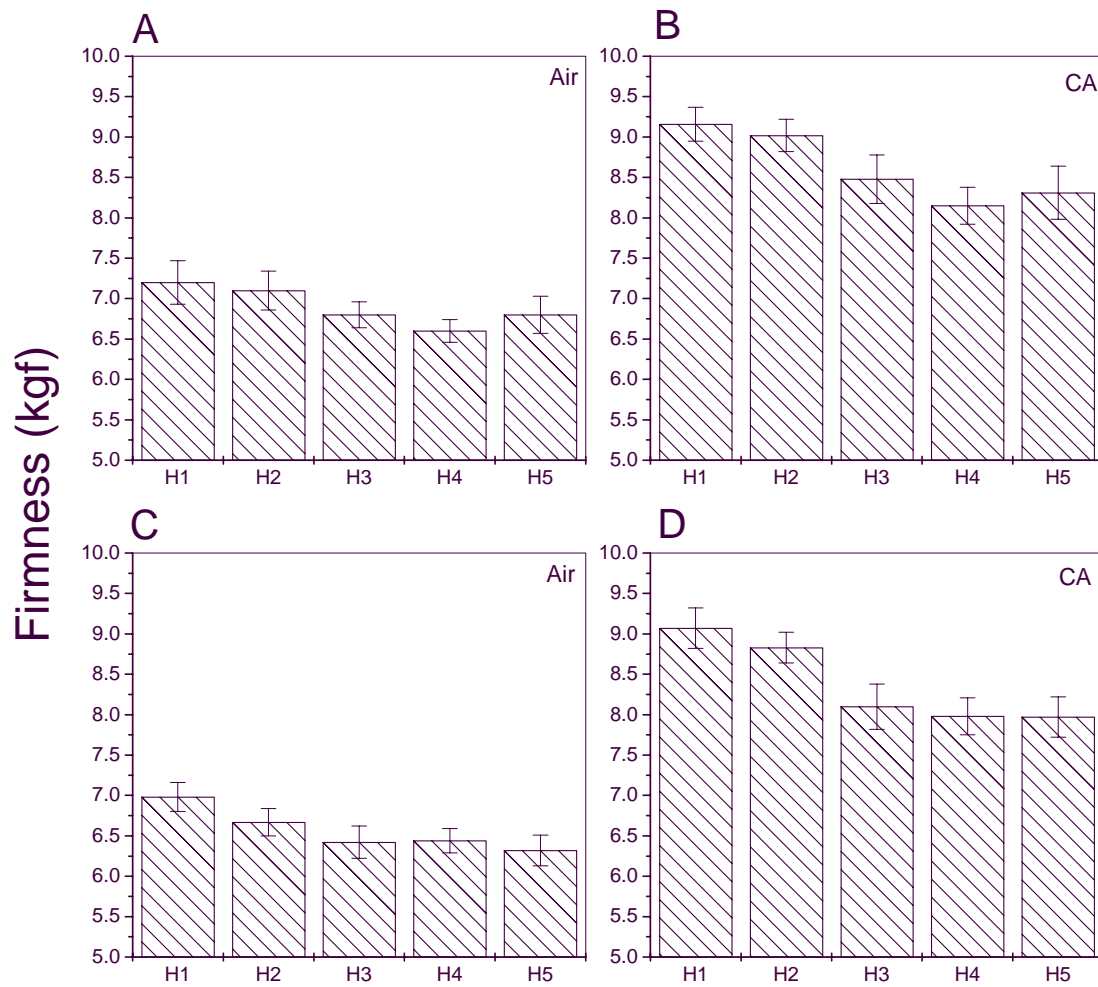


Figure 3. Fruit firmness after 7 days at 20°C following 12 (A, B) or 18 (C, D) weeks of air (A, C) or CA (B, D) storage of Pink Lady apples harvested on 5 occasions. Values are the average 6 orchards of 10 fruit each \pm S.E.M.

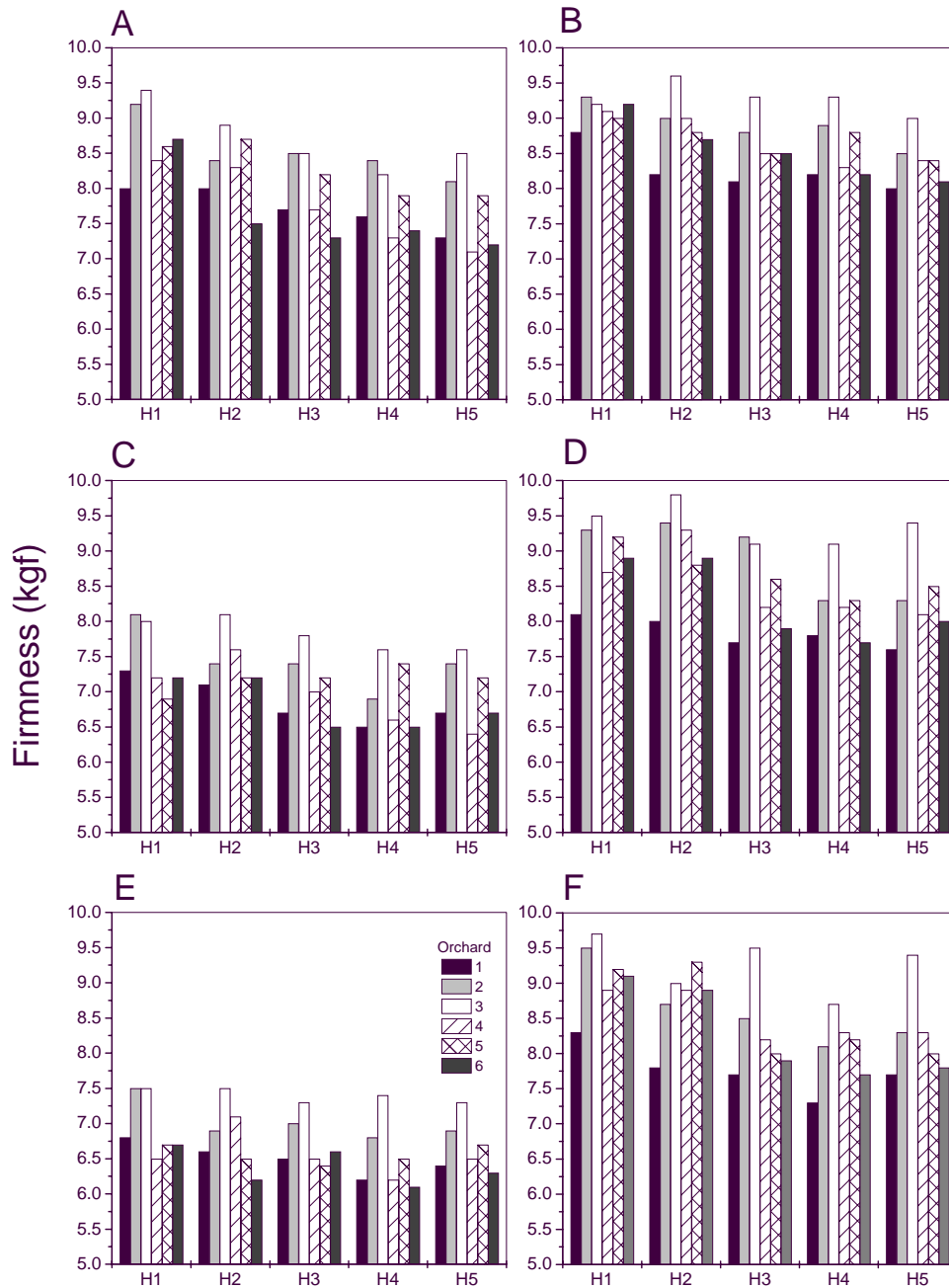


Figure 4. Fruit firmness after 6 (A, B), 12 (C, D) and 18 (E, F) weeks of air (A, C, E) or CA (B, D, F) storage of Pink Lady apples harvested at weekly intervals on 5 occasions (H1, H2, H3, H4 and H5) from Hawkes Bay (orchards 1-3) and Nelson (orchards 4-6). Values are the average 10 fruit.

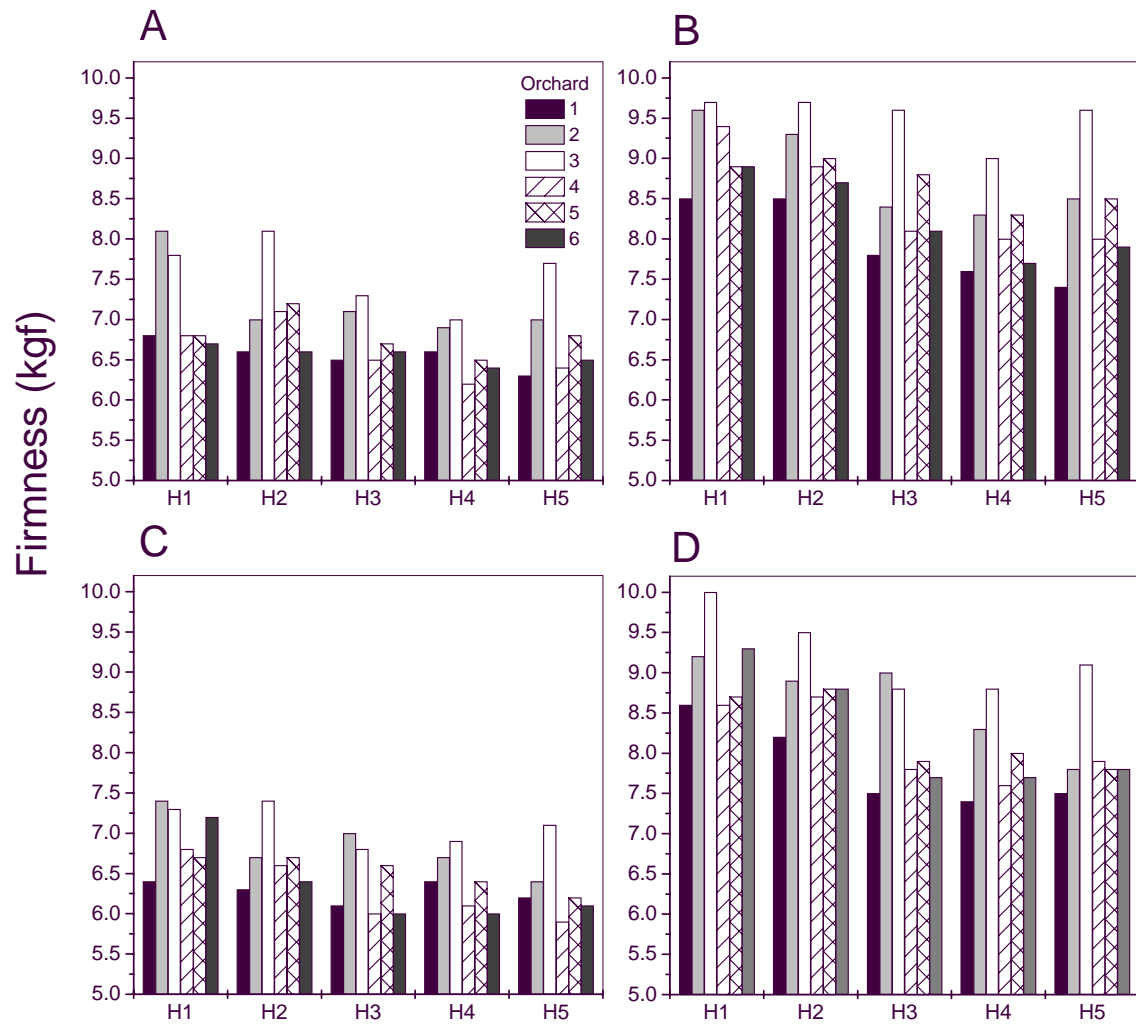


Figure 5. Fruit firmness after 7 days at 20°C following 12 (A, B) or 18 (C, D) weeks of air (A, C) or CA (B, D) storage of Pink Lady apples harvested on 5 occasions from Hawkes Bay (orchards 1-3) and Nelson (orchards 4-6). Values are the average 10 fruit.

4.3 BACKGROUND COLOUR

Background colour as measured with the Braeburn colour cards was higher (less green) with advancing harvest date and increasing storage duration (Fig. 6). After 18 weeks of air storage, the background colour of fruit from H1 and H2 was approximately 5.5 units average of approximately 6.4 units for fruit from H3, H4 and H5. In comparison, the background colour of fruit from H1 and H2 stored in CA were was approximately 4.6 units, compared with 5.6 units for fruit from H3, H4 and H5 after 18 weeks of storage.

After shelf life at 20°C following 12 or 18 weeks of air storage, the average background colour across all orchards was 5.8 and 6.3 units, respectively (Fig. 7). After shelf life at 20°C following 12 or 18 weeks of air storage, background colour was approximately 0.5 units lower (more green) in H1 and H2 compared to H3, H4 and H5. Fruit that had been stored in CA were consistently lower (more green) background colour during storage and after shelf life at 20°C compared to fruit stored in air. Background colour of fruit from individual orchards followed the similar general trends as the orchard averages during storage and after shelf life (Figures 8 and 9, respectively). Orchard 4 tended to have fruit that had slightly greater (more yellow) background colour compared to the other orchards.

Hue angle (°h) generally decreased with advancing harvest date and increasing storage duration. In general, fruit from H1 and H2 had substantially higher °h compared to H3, H4 and H5 during storage and after shelf life at 20°C following air or CA storage (Figures 10 and 11, respectively). During storage and after shelf life at 20°C, fruit from individual orchards followed the similar trends in hue angle °h as did the orchard averages (Figures 12 and 13, respectively). As with background colour measured with a colour cards, orchard 4 tended to have fruit that had lower hue angle (more yellow) during storage relative to the other orchards. Fruit from orchard 4 also had a relatively lower °h compared to other orchards at harvest.

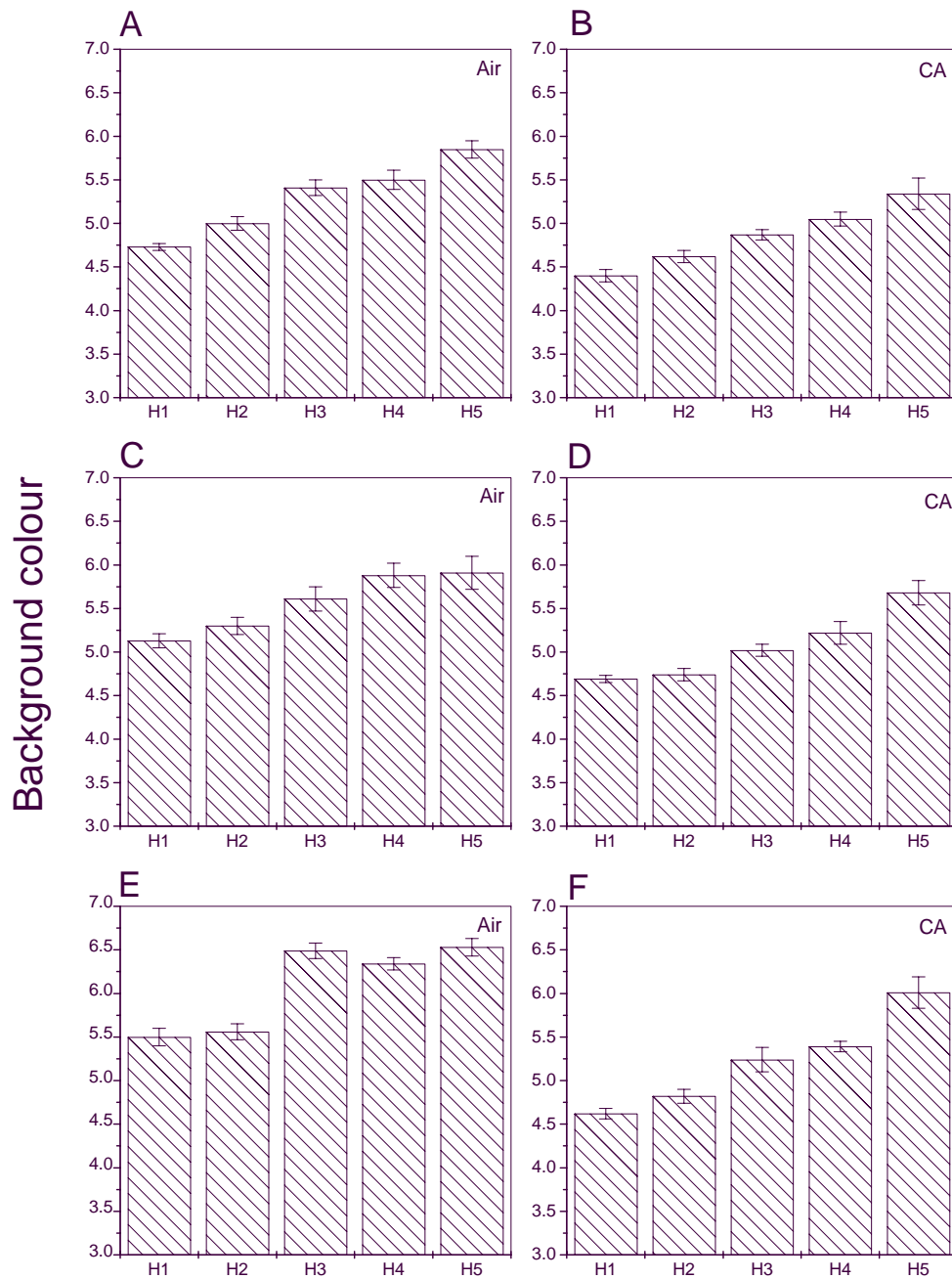


Figure 6. Background colour (units) after 6 (A, B), 12 (C, D) and 18 (E, F) weeks of air (A, C, E) or CA (B, D, F) storage of Pink Lady apples harvested at weekly intervals on 5 occasions (H1, H2, H3, H4 and H5). Values are the average 6 orchards of 10 fruit each \pm standard error of the mean (S.E.M.).

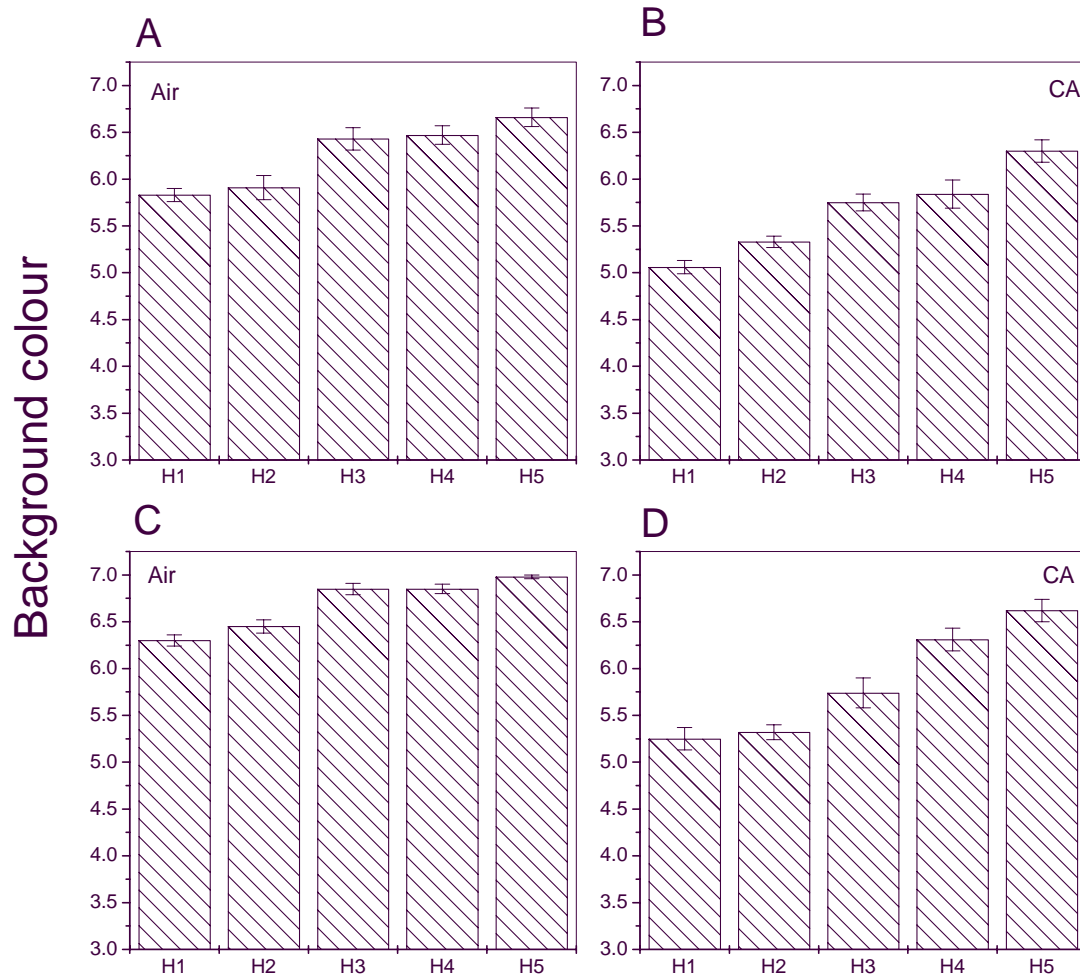


Figure 7. Background colour after 7 days at 20°C following 12 (A, B) or 18 (C, D) weeks of air (A, C) or CA (B, D) storage of Pink Lady apples harvested on 5 occasions. Values are the average 6 orchards of 10 fruit each \pm S.E.M.

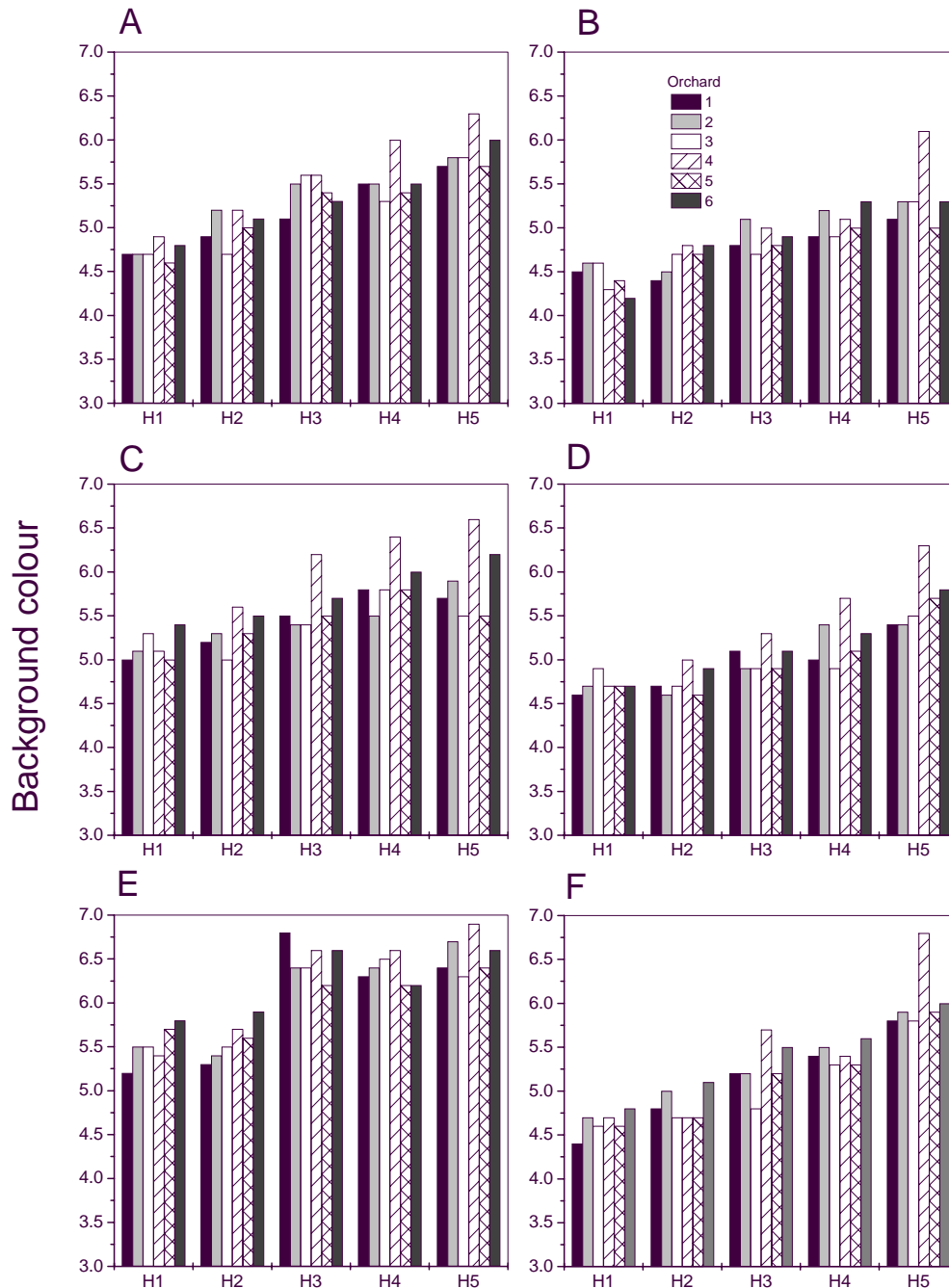


Figure 8. Background colour after 6 (A, B), 12 (C, D) and 18 (E, F) weeks of air (A, C, E) or CA (B, D, F) storage of Pink Lady apples harvested at weekly intervals on 5 occasions (H1, H2, H3, H4 and H5) from Hawkes Bay (orchards 1-3) and Nelson (orchards 4-6). Values are the average 10 fruit.

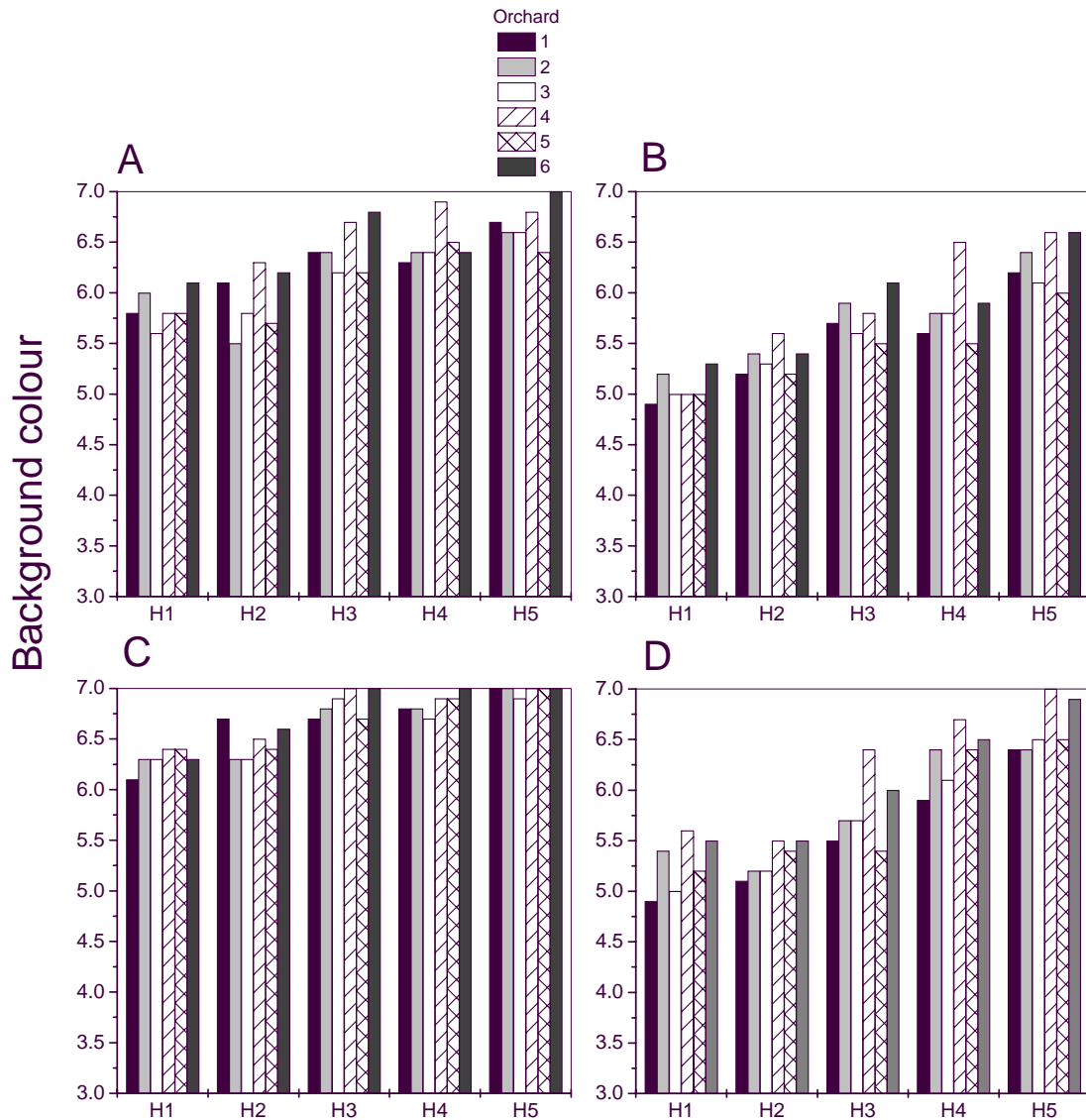


Figure 9. Background colour after 7 days at 20°C following 12 (A, B) or 18 (C, D) weeks of air (A, C) or CA (B, D) storage of Pink Lady apples harvested on 5 occasions from Hawkes Bay (orchards 1-3) and Nelson (orchards 4-6). Values are the average 10 fruit.

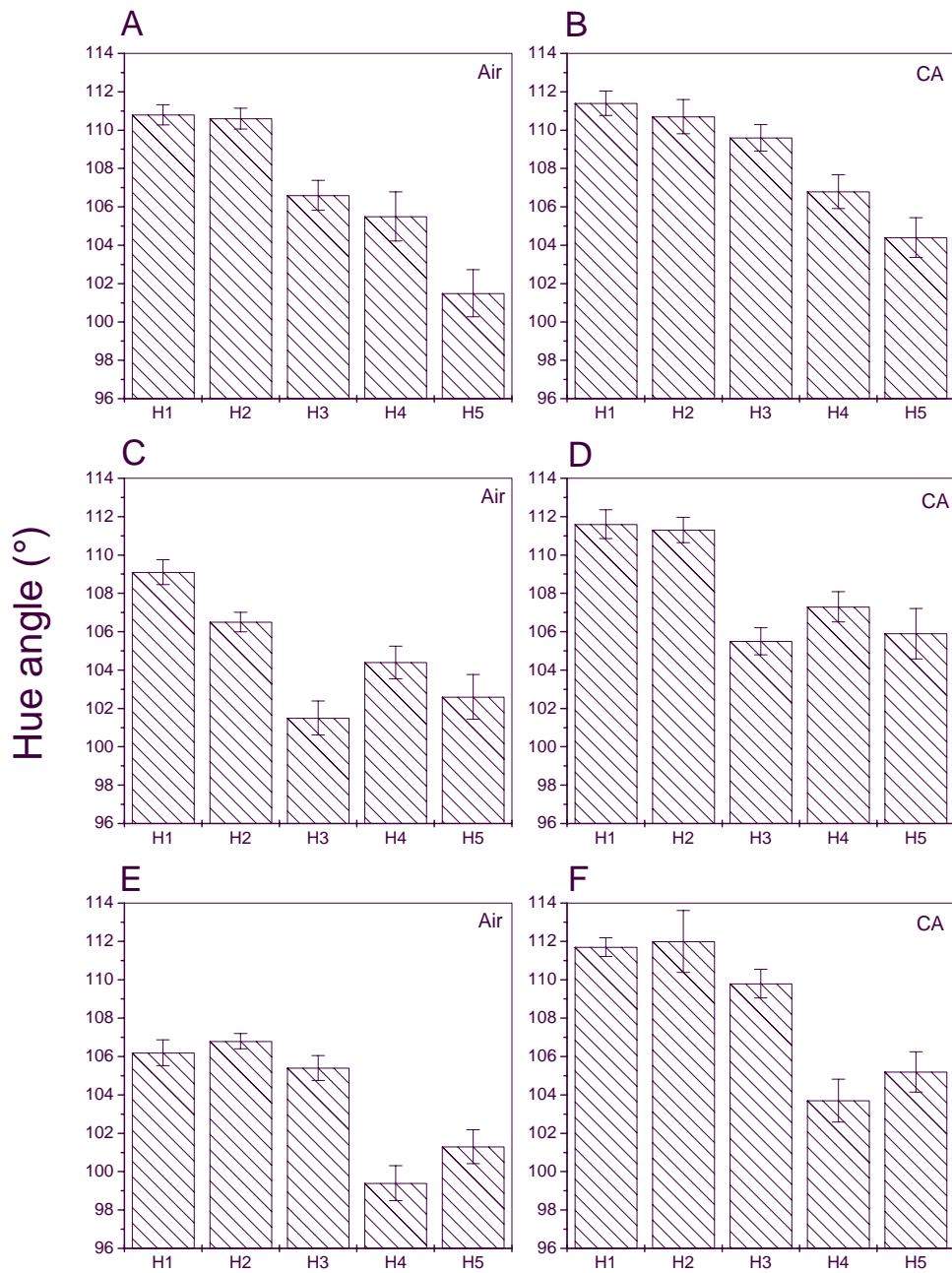


Figure 10. Hue angle (°) after 6 (A, B), 12 (C, D) and 18 (E, F) weeks of air (A, C, E) or CA (B, D, F) storage of Pink Lady apples harvested at weekly intervals on 5 occasions (H1, H2, H3, H4 and H5). Values are the average 6 orchards of 10 fruit each \pm standard error of the mean (S.E.M.).

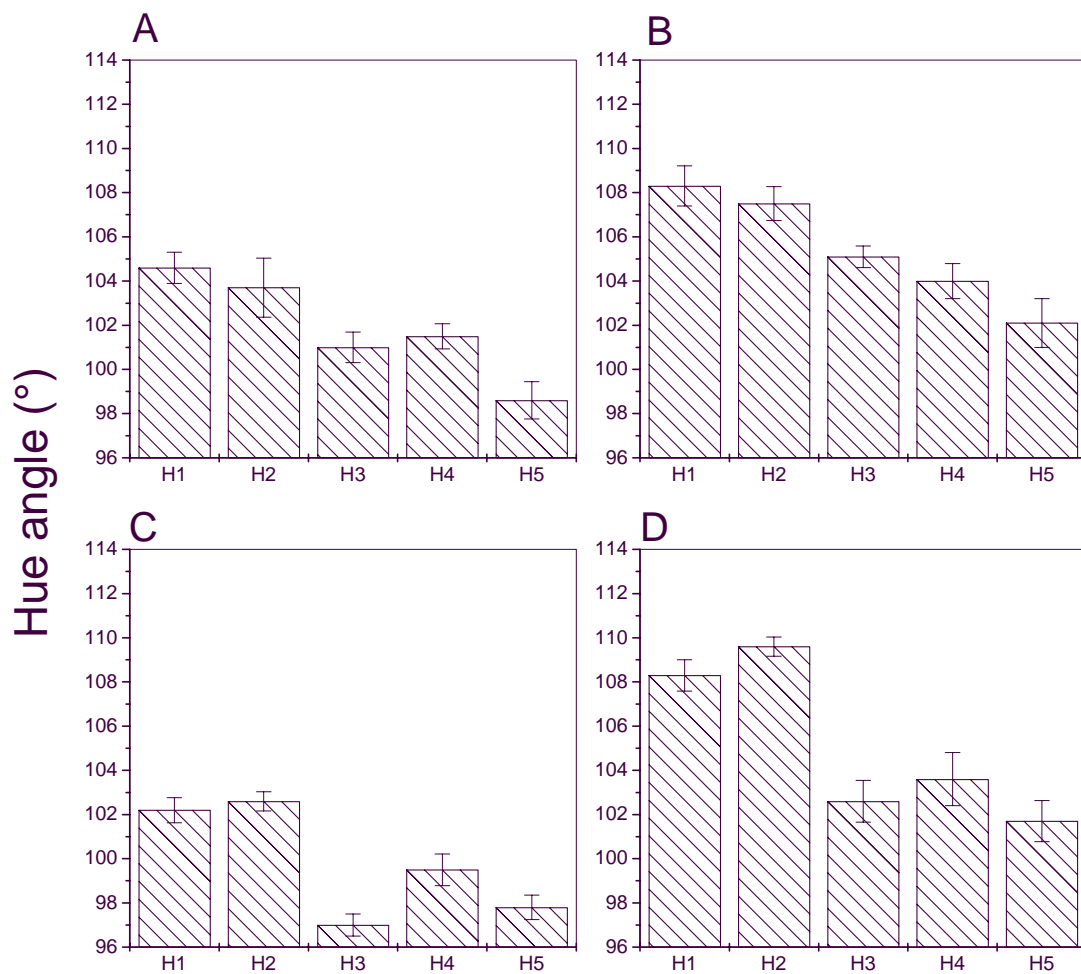


Figure 11. Hue angle (°) after 7 days at 20°C following 12 (A, B) or 18 (C, D) weeks of air (A, C) or CA (B, D) storage of Pink Lady apples harvested on 5 occasions. Values are the average 6 orchards of 10 fruit each \pm S.E.M.

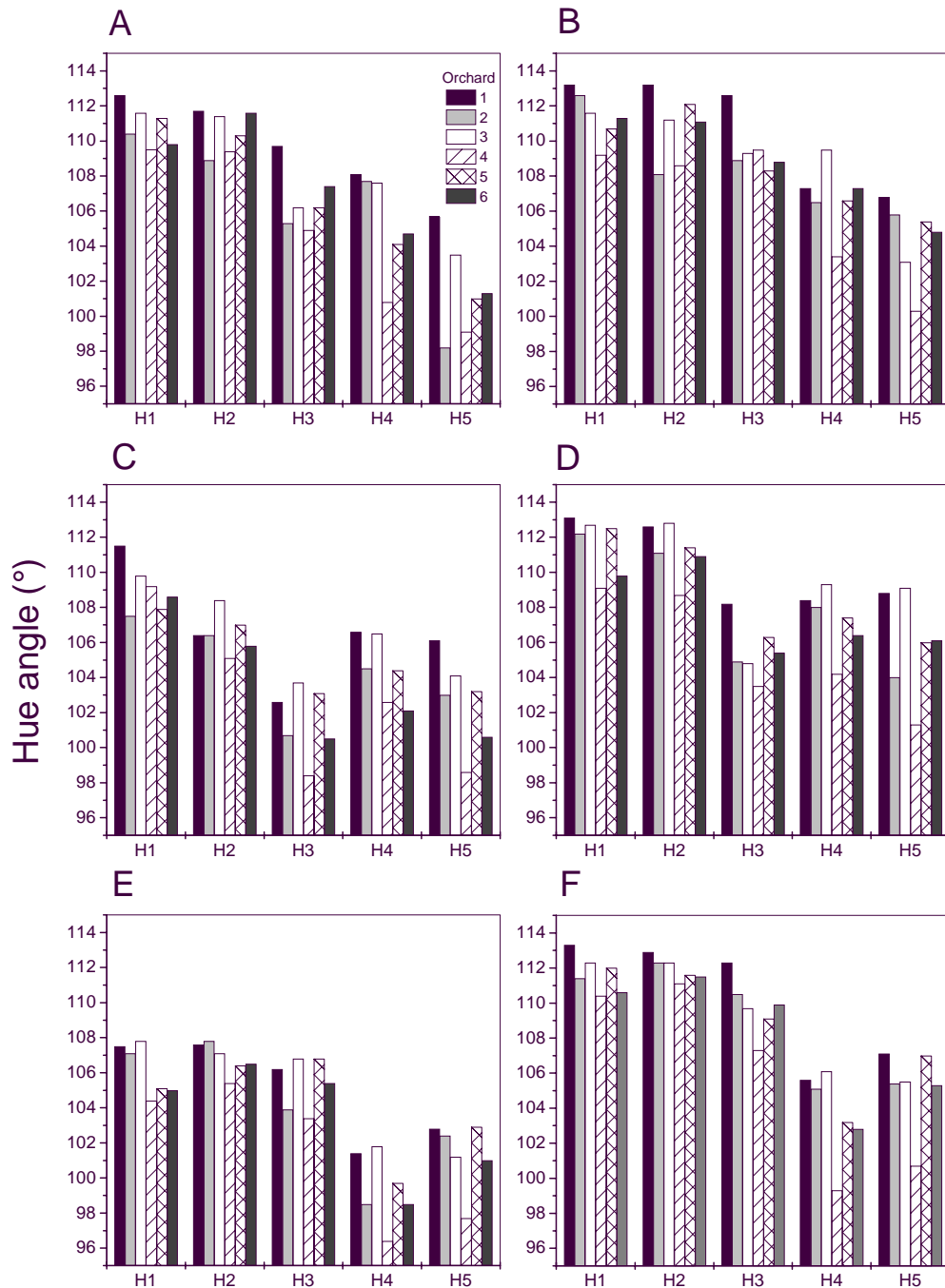


Figure 12. Hue angle (°) after 6 (A, B), 12 (C, D) and 18 (E, F) weeks of air (A, C, E) or CA (B, D, F) storage of Pink Lady apples harvested at weekly intervals on 5 occasions (H1, H2, H3, H4 and H5) from Hawkes Bay (orchards 1-3) and Nelson (orchards 4-6). Values are the average 10 fruit.

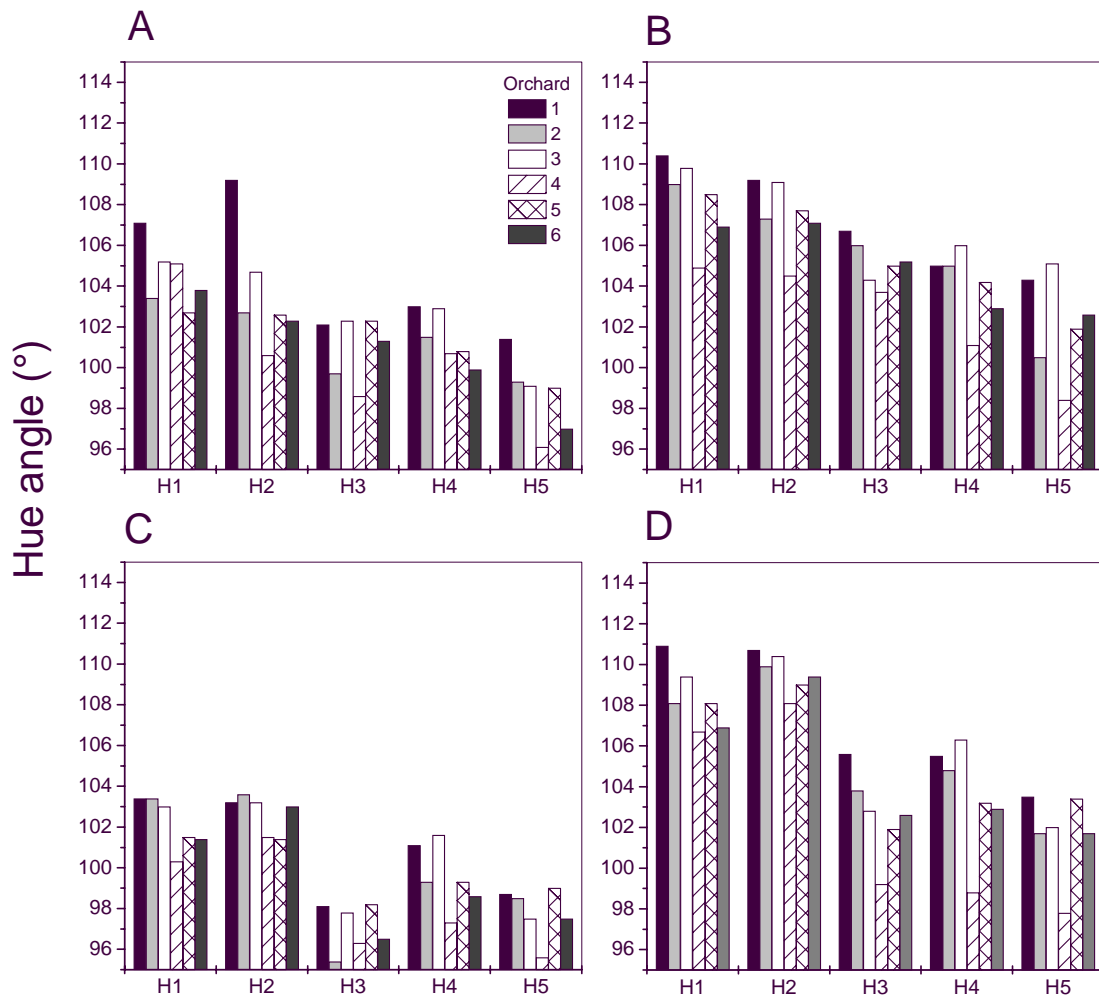


Figure 13. Hue angle ($^{\circ}$) after 7 days at 20°C following 12 (A, B) or 18 (C, D) weeks of air (A, C) or CA (B, D) storage of Pink Lady apples harvested on 5 occasions from Hawkes Bay (orchards 1-3) and Nelson (orchards 4-6). Values are the average 10 fruit.

4.4 SOLUBLE SOLIDS CONTENT

SSC generally increased during storage in fruit from all orchards and harvest dates (Table 5). In H1, H2, and H3, the increase in SSC (%) during storage was approximately 1.2%, and for H4 and H5, SSC increased approximately 0.8% during storage. The SSC (%) was approximately 0.5% greater in fruit stored in CA compared to fruit stored in air. After 7 days at 20°C following 12 or 18 weeks of storage, SSC (%) was similar to levels during storage i.e. there was little or no increase during shelf life (Table 6).

Table 5. The soluble solids content (%) of Pink Lady apples from 6 orchards at harvest and after storage in air or CA for 6, 12 or 18 weeks at 0.5°C. Values are the average of 10 fruit.

Harvest	Week	Storage	Soluble Solids Content (%)						Average
			Orchard						
			1	2	3	4	5	6	
H1	0 (Harvest)		12.1	12.1	12.0	13.4	12.6	13.5	12.6
	6	Air	12.9	13.3	13.0	14.9	13.6	14.5	13.7
		CA	13.2	13.4	13.2	15.2	13.9	14.9	14.0
	12	Air	13.1	13.3	13.3	15.0	14.6	14.8	14.0
		CA	13.3	13.9	13.9	15.3	14.8	15.3	14.4
	18	Air	12.4	13.2	13.2	15.2	14.4	14.4	13.8
CA		13.1	13.9	13.2	15.4	14.7	15.1	14.2	
H2	0 (Harvest)		12.0	12.0	12.6	13.5	12.7	14.0	12.8
	6	Air	12.6	12.9	12.6	14.6	14.3	14.5	13.6
		CA	12.8	12.7	13.2	14.7	14.1	15.1	13.8
	12	Air	12.6	13.2	13.4	15.0	14.4	15.8	14.1
		CA	13.1	13.1	13.6	15.2	14.4	15.5	14.2
	18	Air	12.8	12.8	12.9	14.5	14.2	15.6	13.8
CA		12.9	13.1	13.3	15.0	14.6	15.5	14.1	
H3	0 (Harvest)		11.9	12.4	12.5	13.9	12.4	14.5	12.9
	6	Air	12.5	13.4	13.2	15.0	14.1	15.6	14.0
		CA	12.9	13.0	13.3	15.0	13.9	16.0	14.0
	12	Air	13.0	13.7	13.7	15.0	14.1	15.6	14.2
		CA	13.4	13.7	13.8	15.4	14.4	16.2	14.5
	18	Air	13.0	13.2	13.1	14.8	13.7	16.1	14.0
CA		12.8	13.3	13.6	15.3	14.1	15.6	14.1	
H4	0 (Harvest)		12.4	12.6	13.0	14.2	13.2	15.5	13.5
	6	Air	13.0	13.2	13.5	15.5	14.1	15.9	14.2
		CA	13.3	13.3	13.6	15.5	14.6	15.7	14.3
	12	Air	12.8	13.5	13.8	14.9	14.7	15.9	14.3
		CA	12.7	13.4	14.1	15.5	14.8	16.4	14.5
	18	Air	12.5	13.2	13.1	14.9	14.3	15.5	13.9
CA		12.8	13.4	13.7	15.6	14.8	16.5	14.5	
H5	0 (Harvest)		12.1	12.6	13.2	14.5	13.5	15.1	13.5
	6	Air	12.6	13.2	13.4	15.0	14.2	16.4	14.1
		CA	13.0	13.4	13.9	15.6	14.6	16.3	14.5
	12	Air	12.8	13.1	13.6	14.8	14.3	15.8	14.1
		CA	12.8	13.3	14.0	15.2	14.7	15.7	14.3
	18	Air	12.7	13.4	13.3	14.2	14.4	16.2	14.0
CA		13.5	13.8	14.0	15.3	14.5	15.8	14.5	

Table 6. Soluble solids content (%) of Pink Lady apples from 6 orchards after 7 days at 20°C following storage in air or CA at 0.5°C for 12 or 18 weeks. Values are the average 10 fruit.

			Soluble solids content (%)						
Harvest	Week	Storage	Orchard						Average
			1	2	3	4	5	6	
H1	12	Air	12.9	13.8	13.4	14.9	14.4	14.7	14.0
		CA	13.2	14.0	13.9	15.4	14.8	15.0	14.4
	18	Air	12.8	13.4	12.9	14.4	14.2	14.6	13.7
		CA	13.4	13.5	13.8	14.9	14.2	15.0	14.1
H2	12	Air	13.0	13.0	13.3	15.1	14.7	14.9	14.0
		CA	13.2	13.7	14.0	15.3	14.7	15.5	14.4
	18	Air	12.5	12.9	13.1	14.8	14.2	14.6	13.7
		CA	13.1	13.5	13.8	15.3	14.7	15.5	14.3
H3	12	Air	12.7	13.3	13.5	15.4	13.7	16.2	14.1
		CA	12.9	13.2	14.1	15.7	14.5	15.9	14.4
	18	Air	12.8	12.9	13.0	14.9	14.0	14.8	13.7
		CA	12.8	13.5	13.7	15.3	14.6	16.0	14.3
H4	12	Air	12.8	13.2	13.3	14.7	14.1	15.9	14.0
		CA	13.2	13.5	13.7	15.1	14.5	15.8	14.3
	18	Air	12.0	13.2	13.3	14.3	14.5	15.8	13.9
		CA	13.2	13.5	13.8	15.1	14.5	16.2	14.4
H5	12	Air	11.0	13.1	13.5	15.1	14.3	16.1	13.9
		CA	13.0	13.6	13.8	15.3	14.5	16.4	14.4
	18	Air	12.6	13.0	13.7	14.8	13.8	15.6	13.9
		CA	13.1	13.0	13.7	14.9	14.3	16.3	14.2

4.5 TITRATABLE ACIDITY

Titratable acidity (%) of Pink Lady apples after 18 weeks of storage was relatively unaffected by harvest date (Table 7). Fruit stored in CA had slightly higher acidity averaging 0.46% compared to 0.41% in fruit stored in air. Overall, titratable acidity decreased an average of approximately 0.2% during storage.

Table 7. Titratable acidity (%) of Pink Lady apples harvested on 5 occasions from 6 orchards, after 18 weeks of storage in air or CA. Values represent 3 replicates from 10 fruit.

		Titratable acidity (%)					
Orchard	Storage	Harvest					<i>Average</i>
		H1	H2	H3	H4	H5	
1	Air	0.44	0.45	0.41	0.37	0.40	0.41
	CA	0.48	0.47	0.46	0.43	0.48	0.46
2	Air	0.43	0.41	0.41	0.37	0.37	0.40
	CA	0.50	0.44	0.45	0.43	0.44	0.45
3	Air	0.38	0.38	0.38	0.39	0.40	0.39
	CA	0.44	0.39	0.44	0.40	0.44	0.42
4	Air	0.47	0.40	0.40	0.32	0.35	0.39
	CA	0.51	0.40	0.45	0.41	0.41	0.44
5	Air	0.42	0.44	0.43	0.40	0.43	0.42
	CA	0.52	0.52	0.46	0.47	0.40	0.47
6	Air	0.46	0.44	0.43	0.43	0.45	0.44
	CA	0.57	0.58	0.47	0.52	0.53	0.53

4.6 DISORDERS

Internal browning

After 6 or 12 weeks of storage in CA or air, there was no internal browning in fruit from any of the harvest dates or orchards. After 18 weeks of storage, internal browning occurred at similar levels in fruit stored in CA or air ranging from 1 to 31% in fruit from orchards 4, 5 and 6 (Table 8). The internal browning was expressed as a light diffuse browning that in less severe cases was confined to the core. In the more severe cases the internal browning was darker extending in a radial pattern from the core into the cortical flesh around the vascular bundles. The internal browning increased in incidence and severity during shelf life at 20°C following storage. The internal browning symptoms were mostly slight with approximately 5-25% of the surface of fruit cut at the equator affected with browning.

Superficial scald

Superficial scald did not occur in fruit stored in CA from any of the harvests or orchards. In air storage, superficial scald occurred after 12 and 18 weeks of storage (Tables 9 and 10). The incidence and severity of superficial scald (%) increased with greater storage duration and decreased with later harvest date. Symptoms were typical of superficial scald appearing as a light diffuse browning of the skin that was more prevalent on the green portion of the fruit. The symptoms were not present immediately upon removal from storage but appeared within 1 day at 20°C and increased in severity during subsequent 7 days at 20°C.

Greasiness

There was no greasiness in fruit stored in CA. Greasiness incidence (%) and severity increased with later harvest date and storage duration in air (Tables 11 and 12). There was also a trend for greasiness to occur earlier in storage with later harvest date. In H1, there was no greasiness in fruit from any orchard after 6 and 12 weeks of air storage compared with H2 and H3 where greasiness occurred after 12 weeks. In H4 and H5, greasiness occurred in most orchards and storage durations.

Table 8. Incidence of internal browning (%) in Pink Lady apples after 18 weeks of storage. Values represent percentage incidence in 70 fruit.

		Internal browning (%)					
Orchard	Storage	Harvest					Average
		H1	H2	H3	H4	H5	
1	Air	0	0	0	0	0	0
	CA	0	0	0	0	0	0
2	Air	0	0	0	0	0	0
	CA	0	0	0	0	0	0
3	Air	0	0	0	0	0	0
	CA	0	0	0	0	0	0
4	Air	19	14	6	2	11	10
	CA	25	19	16	22	16	20
5	Air	6	1	1	8	20	7
	CA	3	0	3	14	29	10
6	Air	11	19	31	26	20	21
	CA	16	25	23	26	18	22
Average		7	7	7	8	10	

Table 11. Incidence (%) of greasiness in Pink Lady apples, harvested on 5 occasions from 6 orchards, during storage in air at 0.5°C. Values represent percentage of fruit with greasiness in 10, 20 or 70 fruit at 6, 12 or 18 weeks, respectively.

Greasiness Incidence (%)								
Harvest	Week	Orchard						Average
		1	2	3	4	5	6	
H1	6	0	0	0	0	0	0	0
	12	0	0	0	0	0	0	0
	18	0	0	10	10	5	0	4
H2	6	0	0	0	0	0	0	0
	12	10	0	5	20	0	5	7
	18	0	0	0	5	5	0	2
H3	6	0	0	0	0	0	0	0
	12	5	5	0	60	0	5	13
	18	14	7	21	61	11	36	25
H4	6	0	0	10	100	0	0	18
	12	10	15	45	85	15	30	33
	18	4	20	32	73	16	33	30
H5	6	0	20	30	100	0	30	30
	12	10	15	30	85	0	20	27
	18	34	39	49	81	15	44	44

Table 12. Severity (0-3) of greasiness in Pink Lady apples, harvested on 5 occasions from 6 orchards, during storage in air at 0.5°C. Values represent weighted average of 10, 20 and 70 fruit at 6, 12 or 18 weeks, respectively.

Greasiness Severity (0-3)								
Harvest	Week	Orchard						Average
		1	2	3	4	5	6	
H1	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	18	0.0	0.0	0.1	0.1	0.1	0.0	0.1
H2	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12	0.1	0.0	0.1	0.2	0.0	0.1	0.1
	18	0.0	0.0	0.0	0.1	0.1	0.0	0.0
H3	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	12	0.1	0.1	0.0	1.0	0.0	0.1	0.2
	18	0.1	0.1	0.2	0.8	0.1	0.3	0.3
H4	6	0.0	0.0	0.1	1.0	0.0	0.0	0.2
	12	0.1	0.2	0.7	1.2	0.2	0.3	0.5
	18	0.2	0.2	0.4	0.9	0.2	0.3	0.4
H5	6	0.0	0.2	0.3	1.0	0.3	0.0	0.3
	12	0.1	0.2	0.4	1.1	0.0	0.2	0.3
	18	0.4	0.4	0.6	1.0	0.2	0.4	0.5

5. DISCUSSION

New Zealand apples for export are stored in 3 distinct time-related phases: on-shore, during shipment, and offshore. Pink Lady apples are usually accumulated in on shore storage facilities over approximately 4 to 6 weeks during the harvest season and stored in bins in air storage, then packed and shipped in charter vessels or integral shipping containers, in CA or air, to the United Kingdom (UK) and Europe. Distribution from the market requires approximately a further 4 weeks. Once in the market, Pink Lady fruit will likely have a subsequent period of storage of up to several weeks. Therefore, Pink Lady apples grown in New Zealand for export are likely to have a total duration of storage in the range of 12 to 16 weeks.

A specification for Pink Lady requires firmness to be a minimum of 6.5 kgf, at out-turn. In this study, fruit stored in air for more than 12 weeks would be unlikely to meet this requirement irrespective of harvest date. In contrast, fruit stored in CA were more than 7.5 kgf after 18 weeks of storage. In addition, some loss of texture had occurred in fruit stored in air for 12 weeks or more, whereas a crisp texture was maintained in CA-stored fruit.

The most marked effect of harvest date was on background colour retention in storage. In general, the later the harvest, the less green the background colour during storage. In both CA and air, fruit from H1 and H2 retained more green colour compared to H3, H4 and H5 during storage and shelf life. Although no specific out-turn specification is given for Pink Lady, a lime green background colour is considered to be desirable quality attribute. Assessment and quantification of green colour changes in Pink Lady was difficult due to poor correspondence with colour changes of Pink Lady with the Braeburn colour card series. In this study, a background colour of less than 5.0 units, and a °h greater than 108° were considered to have a “lime green” background colour. A °h of less than 106° was considered to have a yellow appearance while °h of between 106-108° was judged to be marginal having some green colour but more nearly all yellow. Using these criteria, fruit stored for more than 6 weeks in air are unlikely to retain a “lime” green background colour irrespective of harvest date. In contrast, fruit from H1 and H2 and stored in CA are likely to have less than 5.0 units background colour and greater than 108° hue angle during 18 weeks of storage and 7 days shelf life.

Fruit from all harvests and orchards met minimum requirements of 40% blush coverage, and greater than 13.0% SSC after storage. The data indicate that SSC of Pink Lady can increase nominally by about 1% during air or CA storage. Although SSC in Pink Lady is undoubtedly subject to variation being lower in some growing seasons, it seems unlikely that delaying harvest to attain fruit with higher SSC is useful or necessary. This is especially true considering that attaining higher SSC would be at the expense of loss of other quality attributes such as firmness and background colour during storage.

Three disorders that can occur during storage of Pink Lady are internal browning, greasiness, and superficial scald. The occurrence of internal browning in Pink Lady is of major concern especially with respect to the use of CA storage. There are several reasons why it is not likely that CA is a causative factor in inducing internal browning in Pink Lady. Internal browning occurred in fruit after 18 weeks of air or CA storage. The symptoms observed were a light diffuse browning that occurred near the vascular bundles rather than the dark brown water soaked appearance associated with disorders that are increased by CA (eg. Braeburn browning disorder (BBD); internal browning in Fuji). The physical appearance and timing of occurrence (late in storage) of the disorder in storage indicate that it is more likely the fruit

beyond were its' useful storage life rather than a CA injury i.e. it is a senescence-related disorder and not a CA-related disorder. The fact that internal browning only occurred in fruit from orchards in the Nelson district indicates that there is a seasonal predisposition that influences on the susceptibility of Pink Lady to internal browning.

The data in this study indicate that measures to control superficial scald occurrence in Pink Lady are necessary. Superficial scald is a low temperature injury of apples that occurs during storage for periods greater than approximately 3 months. A postharvest drench with the antioxidant diphenylamine (DPA) is commonly used to control the disorder. Commercially, CA storage has been demonstrated to provide adequate control of superficial scald of apples but its effectiveness is contingent upon establishment of CA relatively soon after harvest (eg. less than a week). CA protocols to control superficial scald without use of DPA have not been tested for New Zealand grown Pink Lady. If the storage duration is to be less than 8 weeks, then the use of DPA may not be necessary. Otherwise, the current practise of drenching fruit at harvest with (DPA) at 300ppm is likely to provide satisfactory control of superficial scald for up to 16 weeks of storage.

The later the harvest, the greater the greasiness incidence and the earlier the occurrence in air storage. Greasiness occurred at relatively low incidence and severity in H1 and H2 compared to H3, H4 and H5. CA provided complete control of greasiness in all orchards and harvests throughout 18 weeks of storage and shelf life. Similar to superficial scald, the sooner that CA is established after harvest the more effective CA would be in reducing greasiness in Pink Lady. However, the extent to which the effectiveness of CA in reducing greasiness is decreased with increasing delay between harvest and CA establishment has not been quantified.

Of the fruit characteristics that are used to determine when to begin harvest, SPI and background colour exhibited the most change over the harvest period. SPI is the key criteria used to determine harvest date for Pink Lady. However, the SPI at harvest did not relate well to storage behaviour of Pink Lady apples in other than very general terms. Although the fruit with more advanced SPI at harvest had lower firmness and higher background colour (more yellow), the SPI was not useful as a quantitative measure of storage potential. Current specifications are that the average SPI for an orchard should be greater than 1.0 before harvest commences. Using this as the harvest parameter, the first harvest in orchards 4, 5 and 6 would have been between the 9th and 17th of April (between harvests 2 and 3). By the 2nd of April the minimum blush and SSC requirements of fruit in these orchards had already been attained. In addition, loss of firmness and green colour on the tree had already begun. Conversely, fruit with an SPI of up to 3.5 are still within requirements for export in ESP category C. Thus, fruit from some of the orchards in H4 and H5 would have been considered suitable for export even though the propensity for firmness and colour loss and disorders in storage was relatively high.

The differences in SPI between orchards 1, 2 and 3 compared to 4, 5 and 6 were likely to be seasonal differences related to weather conditions rather than specific to the two growing districts. Thus, specifying different harvest parameters for Hawkes Bay and Nelson is not appropriate. A more practical approach may be not to set a minimum value for SPI to attain for harvest to begin, but to consider changes in SPI in relationship to other fruit characteristics particularly firmness and background. The data in this study indicate that fruit had attained blush and SSC requirements before SPI had increased to greater than 1.0 in all orchards. Once the SPI has begun to change the biological process of starch hydrolysis will continue during storage. Therefore, provided blush coverage and SSC are satisfactory, there is no reason to delay harvest simply to attain higher SPI particularly if fruit losses in firmness and background colour are occurring. Conversely, if SPI is increasing but firmness and

background colour are not changing greatly then harvest could be delayed. This approach requires repeated sampling of maturity at regular intervals so that rate of change in SPI, firmness and colour can be assessed over time. This type of evaluation of maturity data could overcome the reliance on set values of maturity characteristics that are static and inflexible do not adjust to environmental and seasonal variation and do not consistently relate well to each other or fruit storage behaviour.

Overall, considering firmness, green background colour, and the occurrence of disorders in storage, the optimum harvest dates for long term storage in CA (greater than 12 weeks) or air (less than 12 weeks) of Pink Lady in this study were H1 and H2. In H1 and H2, the minimum requirements of blush coverage and SSC were attained with markedly better retention of firmness, green background colour and lower risk of greasiness in storage compared to H3, H4 and H5. Fruit from H3 were marginal and probably suitable for short to mid term storage (6-12 weeks) depending upon the orchard and only if stored in CA.

To best maintain the fruit quality attributes of Pink Lady during storage, the best scenario would be to have fruit under CA conditions with 1 week of harvest followed by CA shipment in integral shipping container or charter vessel. In previous studies, we have demonstrated that the benefits of CA storage are maximised if fruit are placed in CA within a week of harvest. In Cox's Orange Pippin when CA application is delayed losses in firmness can be up to 0.7 kgf per week (Burmeister et al., 1997, 1998b, and 1999). In Fuji apples, after 12 weeks of storage, a delay in establishment of CA of 4 weeks results in fruit stored in CA being similar firmness to air-stored fruit. (Burmeister et al., 2000).

In this study, during the first 6 weeks of air storage of Pink Lady apples, the average firmness or background colour loss was 1.0 kgf or 1.1 units, respectively. A storage duration of 6 weeks is approximately the time expected for on-shore storage of Pink Lady. Therefore, this implies that a substantial portion of the benefits of CA storage would be lost if fruit are not stored in CA during the first several weeks after harvest. Although fruit are likely to benefit from CA during the shipment following air storage on shore, much of the benefits in retention of firmness and background and reducing disorders in comparison to air storage would be lost.

6. CONCLUSIONS

It is concluded that:

- Pink Lady apples stored in air at 0.5°C for greater than approximately 12 weeks are unlikely to be greater than 6.5 kgf firmness irrespective of harvest date.
- Fruit stored greater than 6 weeks in air at 0.5°C is unlikely to retain a “lime green” background colour irrespective of harvest date.
- Fruit from H1 and H2 but not H3, H4 and H5 are likely to retain “lime” green background colour during storage and shelf life at 20°C for up to 18 weeks of CA, or 12 weeks of air storage.
- Overall, considering firmness, green background colour, and the occurrence of disorders in storage, the optimum date for Pink Lady would be approximately the last week of March to the start of April depending upon the orchard.
- Current harvest parameters (ESP specifications) are not appropriate for Pink Lady. A specification of an SPI of 0.5-1.0 at harvest is likely to be appropriate, since at this SPI all fruit in this study had minimum blush coverage of 40% and SSC of 12%.
- Fruit from all orchards harvested at approximately 12% SSC attained greater than 13.0% SSC after storage.
- CA storage established within 7 days of harvest is recommended for Pink Lady to increase firmness and background colour retention and to reduce the risk of storage disorders in particular greasiness. An atmosphere of 2% O₂:2% CO₂ is likely to be appropriate.
- CA may not be a causative factor in internal browning in Pink Lady.
- The data in this study indicate that measures to control superficial scald occurrence in Pink Lady are necessary. The current practice of drenching fruit at harvest with diphenylamine (DPA) at 300ppm is likely to provide satisfactory control of superficial scald for up to 16 weeks of storage.

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