LOW TEMPERATURE LIMITS OF NEW ZEALAND 'HASS' AVOCADO FRUIT

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ABSTRACT

New Zealand avocados have an eight month harvest season from late August to early March where the month of harvest affects the incidence and severity of rots and chilling injury. Late season, high maturity fruit have high levels of ripe rots and chilling injury when stored longer than 28 days. In South Africa the sensitivity of avocado fruit to chilling injury is thought to decrease as the harvest season progresses in contrast to late season New Zealand 'Hass' avocado fruit where chilling injury symptoms become worse. Implying 'Hass' avocado fruit harvested after February should not be exported. The aim was to refine the chilling injury relationship of 'Hass' avocado fruit to temperature and storage duration for fruit harvested in February and March. The development of chilling injury symptoms on the skin of 'Hass' avocado fruit was dependent on the storage temperature and duration. The minimum time the fruit took to develop discrete patches was 11 days at 1°C or 2°C with longer times needed at warmer temperatures. The mass loss where discrete patches began to increase was 2% for February harvested fruit. Such a low mass loss before chilling injury appeared highlighted the need to control mass loss form late season fruit. Fruit harvested in February had greater chilling injury symptoms than fruit harvested in April. The fruit from different orchards had different susceptibility to developing chilling injury. The fruit in this study developed high amounts of brown patches and stem end rots typical of late season fruit. The greatest amounts of ripe rots were, generally, at the lowest temperatures suggesting that there was damage to the tissue that increased the expression of ripe rots. Chilling injury risk was related to the storage duration where the fruit appear to be able to tolerate a short period of low temperature. If the fruit need two weeks storage then temperatures below 4°C could be used providing ripe rots could be controlled. Hass avocado fruit harvested in February have a high risk of developing chilling injury at temperatures below 4°C when stored for 28 days. When harvested in April the risk of chilling injury is greatly lower than for the February harvested fruit and storage below 4°C may be possible.

Keywords: chilling injury, ripe rots, storage, maturity

INTRODUCTION

The New Zealand avocado industry exports fresh 'Hass' avocados (*Persea americana* Mill.) over long distances to Australia, the USA, Japan and South East Asia. For the fruit to arrive with good quality the post-harvest handling chain must be based on effective temperature management. The avocado fruit is generally considered to be a chilling sensitive fruit where long storage near 5°C the fruit will show chilling injury symptoms (Arpaia, 2005). New Zealand avocados can be harvested for export over eight months starting in late August (late winter) and finishing in early March (late autumn). For New Zealand 'Hass' avocados the month of harvest affects the incidence and severity of rots and chilling injury. Over the harvest season the fruit dry matter, as a measure of maturity, can increase from 24% to about 36% (Dixon *et al.*, 2003). The impact of increasing fruit maturity on the quality of avocado at low storage temperatures is that late season and high maturity fruit can have the greatest levels of ripe rots and chilling injury when stored longer than 28 days (Dixon *et al.*, 2003, Dixon *et al*., 2004). These findings confirmed the recommendation that for optimal quality New Zealand 'Hass' avocados be stored at 4°C to 6°C for up to 4 weeks (Hopkirk *et al.,* 1994). However, in other storage trials 'Hass' fruit stored at 2°C for 4 weeks had good quality with 83% sound fruit

(Dixon *et al.*, 2004), in contrast to fruit maintained at 0°C or 2°C developing chilling injury symptoms and a high incidence of rots after 2 weeks storage (Hopkirk *et al.*, 1994). Research in South Africa has suggested that the sensitivity of avocado fruit to chilling injury decreases as the harvest season progresses (Toerien, 1986). These findings contrast with observations on late season New Zealand Hass avocado fruit, harvested in February, where chilling injury symptoms can become worse (Dixon *et al.*, 2003; Dixon *et al.*, 2004) but only after 28 days storage.

New Zealand 'Hass' avocados have the potential to be harvested for export beyond February where the influence of maturity on chilling sensitivity characteristics of New Zealand 'Hass' avocados is not known. Should chilling injury symptoms become worse on fruit harvested after February this would define a harvest window for 'Hass' avocados to be exported from New Zealand. The experiments reported here aim to further refine the chilling injury response of New Zealand 'Hass' avocado fruit to temperature and time in storage for fruit harvested in February and March.

MATERIALS AND METHODS

'Hass' avocado fruit were sourced from two commercial avocado orchards in the Te Puke area of Bay of Plenty region. Each orchard was harvested twice, once in February (8-9/2/2007) and again in April (26-27/4/2007). A total of 1,100 fruit were taken at each harvest from each orchard. Within four hours of harvest the ungraded fruit, were weighed and packed into trays of 20 fruit. The trays of fruit were placed into temperature controlled cabinets at 1°C, 2°C, 3°C, 4°C or 5°C ± 0.5°C, 85% ± 5% relative humidity. A total of 100 fruit (5 trays of 20 fruit) per orchard per harvest were stored for 14 or 28 days at each temperature before removal to 19.5 ± 1°C, 65% ± 5% relative humidity for ripening. At each harvest a non-stored control sample of 100 fruit per orchard per harvest was ripened at 19.5 ± 1°C, immediately after harvest. An additional 20 fruit sample from each harvest from each orchard was assessed for percentage dry matter by drying flesh peelings from the inside face of one quarter of each fruit after the seed, seed coat and skin were removed.

During storage, every three to four days, each fruit was weighed and assessed for external disorders on the peel according to the Avocado Industry Council Fruit Assessment Manual (Dixon, 2003). The fruit stored for 14 days was assessed 5 times and the 28 day stored fruit 9 times. After removal from storage fruit were again weighed and inspected for external disorders and once eating ripe were assessed for internal disorders according to the Avocado Industry Council Fruit Assessment Manual. Chilling injury was considered to be a physiological disorder while fuzzy patches on the skin of the fruit were, generally, considered to be fungal in origin. The severity and incidence of the external skin disorder discrete patches was considered to be a measure external chilling injury while the severity and incidence of diffuse flesh discolouration was considered to be a measure of internal chilling injury.

Results were analysed by One Way ANOVA using Tukey's family error rate of 5% using MINITAB version 13.31.

RESULTS

The fruit used in this experiment had average dry matter content on 9/2/2007 of 37.55% for Orchard A and 33.80% for Orchard B. The fruit harvested six weeks later on 27/4/2007 had average dry matter contents of 34.02% for Orchard A and 34.71% for Orchard B. The time taken to ripen after storage was generally, longest at 1°C and 2°C, after 14 days storage, for the February harvested fruit and for the fruit harvested from Orchard B which had the lowest average dry matter in February (Table 1).

Discrete patches on the skin of the fruit were the most obvious indication of chilling injury during storage. Discrete patches became visible after 11 days at 1°C and 2°C and 14 days at 3°C (Figure

Table 1. Ripening time of late season 'Hass' avocado fruit stored for 14 or 28 days at low temperatures after harvest in February and April.

Ripening time (days)								
Harvest	**9/2/2007**				**27/4/2007**			
Storage time (days)	**14**		**28**		**14**		**28**	
Orchard	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Non-stored	**9.8**	**11.2**			**7.5**	**7.4**		
Temperature								
1°C	8.0a	6.9b	7.3ac	7.0	5.2	5.0a	4.6a	5.0a
2°C	7.6a	8.1ab	7.7a	7.5	5.3	5.0a	4.6a	4.6a
3°C	5.6b	8.1a	6.4bc	7.3	5.0	4.7b	4.1a	4.0b
4°C	5.6b	7.1ab	5.6b	6.9	5.1	4.6b	3.3b	3.6b
5°C	6.7ab	7.3ab	5.9b	7.6	5.2	4.8b	4.2a	3.8b
Average	6.7	7.5	6.6	7.3	5.2	4.8	4.2	4.2

1a). Discrete patches were observed at very low incidence and severity during 4°C and 5°C after 21 days storage (Figure 1a). The fruit harvested in April had an overall lower incidence and severity of discrete patches compared to the fruit harvested in February (Figure 1) with the external chilling injury becoming visible after 11 days storage at all temperatures.

Fruit from Orchard A developed discrete patches that were about twice the size of the discrete patches that developed on fruit from Orchard B when the fruit were stored at 1°C and harvested in February after 28 days storage (Figure 2a). The incidence of discrete patches was similar between the orchards (Table 2). The fruit harvested in April developed smaller discrete patches (Figure 2b) and

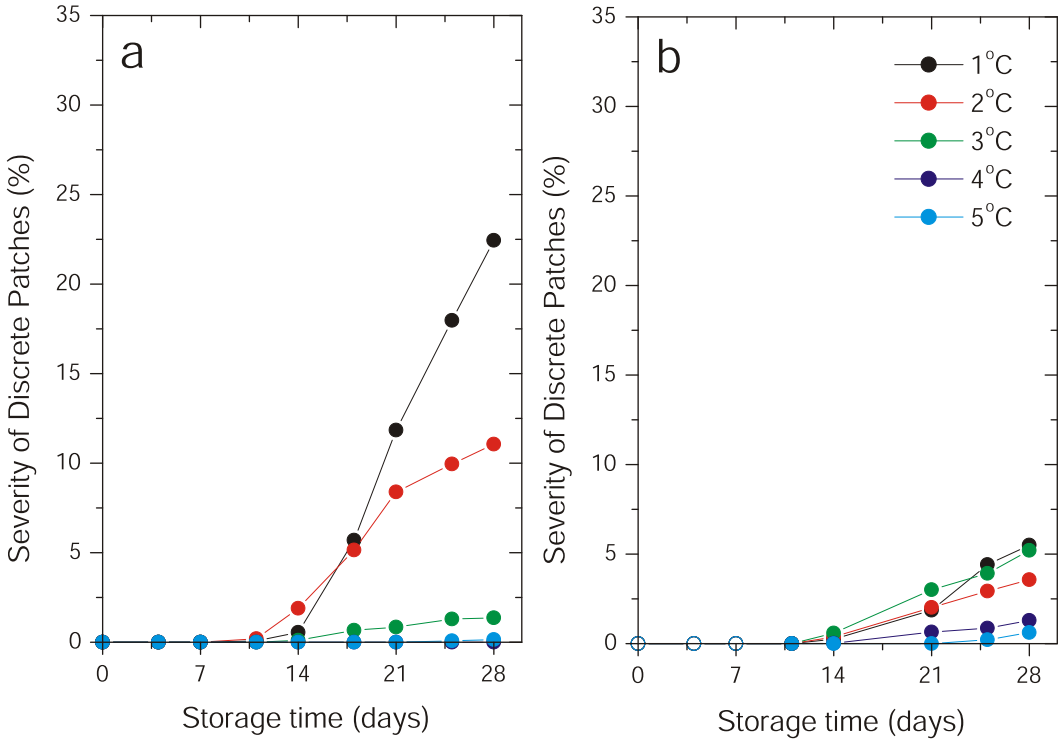

Figure 1. Average severity of Discrete Patches on 'Hass' avocado fruit maintained for 28 days at low temperatures after harvest on a) 9/2/2007 and b) 27/4/2007

at a lower incidence than the fruit harvested in February across both growers (Tables 2 and 3). The severity and incidence of discrete patches was similar on the fruit from Orchard A and Orchard B when the fruit was harvested in April.

For the February harvested fruit, the incidence and severity of discrete patches after storage was generally, greatest at 1°C and 2°C, after 28 days storage and was similar between orchards (Table 2). The severity and incidence of internal chilling injury, diffuse flesh discolouration, was very low after 14 days storage and continued to be very low at 28 days storage across all temperatures (Table 2). For April harvested fruit, the severity and incidence of diffuse flesh discolouration after 14 days storage across all temperatures was very low for fruit from both orchards (Table 3). Fruit from Orchard B after 28 days had a low severity and incidence of diffuse flesh discolouration but at 4°C and 5°C rather than 1°C or 2°C (Table 3).

For the February harvest fruit the severity of fuzzy patches was generally low but the incidence was high across all temperatures (Table 2). The severity and incidence of fuzzy patches was greater in fruit from Orchard B than from Orchard A (Table 2). The severity and incidence of fuzzy patches was not related to the duration of storage. Fuzzy patches were less severe and had a lower incidence in the fruit harvested in April from both orchards, at each storage duration and across all temperatures (Table 3). The incidence of fuzzy patches after 28 days storage was lower than after 14 days storage (Table 3).

For February harvested fruit the severity of discrete patches was associated with a mass loss of about 2% when stored at 1°C to 3°C (Figure 3a).Once the mass loss exceed 2% the severity of discrete patches increased exponentially to high levels at 1°C and 2°C. For April harvested fruit the threshold of mass loss where discrete patches increased was lower at about 1% (Figure 3b) and there was the same pattern of exponential increase in discrete patches with mass loss.

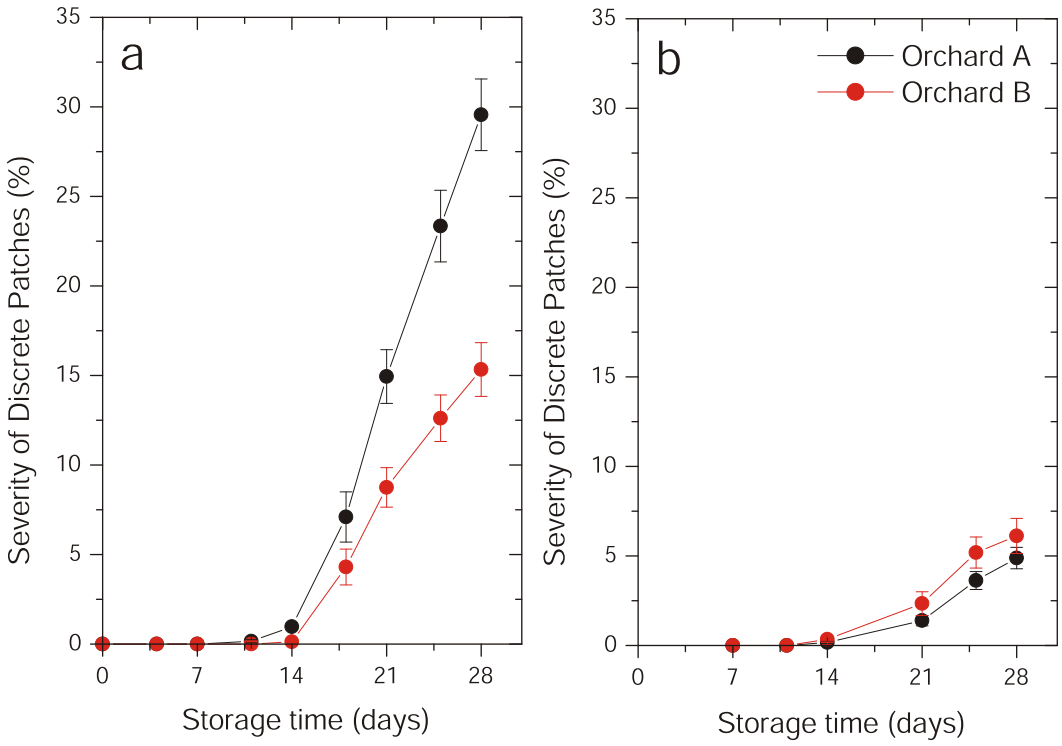

Figure 2. Average severity of Discrete Patches on 'Hass' avocado fruit maintained for 28 days at 1°C after harvest on a) 9/2/2007 and b) 27/4/2007

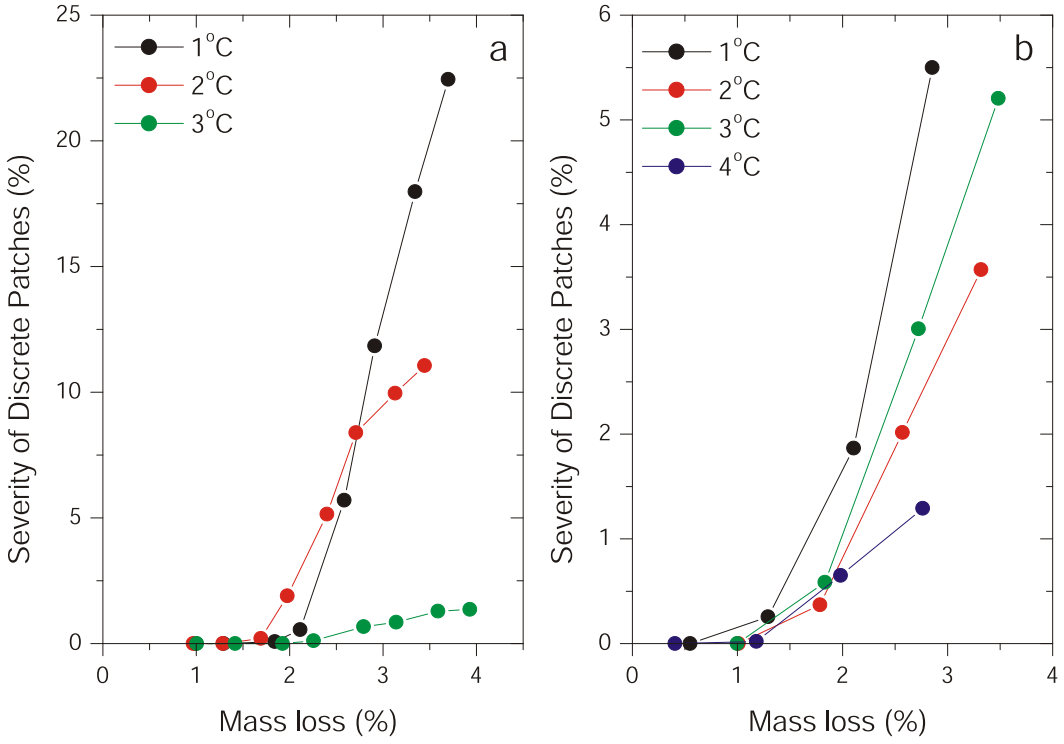

Figure 3. Relationship between average severity of discrete patches on 'Hass' avocado fruit maintained at different temperatures for 28 days harvested on a) 9/2/2007 and b) 27/4/2007

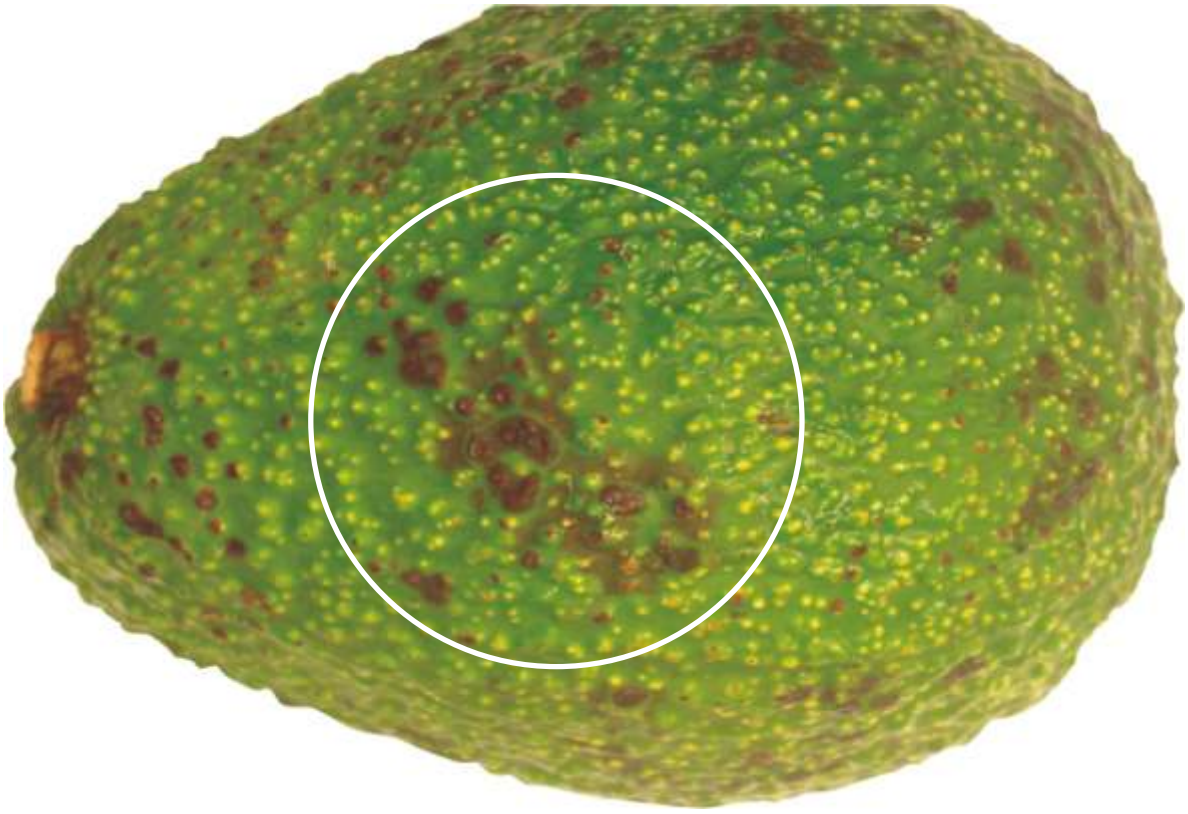

Figure 4. Discrete patches and fuzzy patches on the skin of a 'Hass' avocado fruit after 14 days at 2°C, harvested in February from Orchard B.

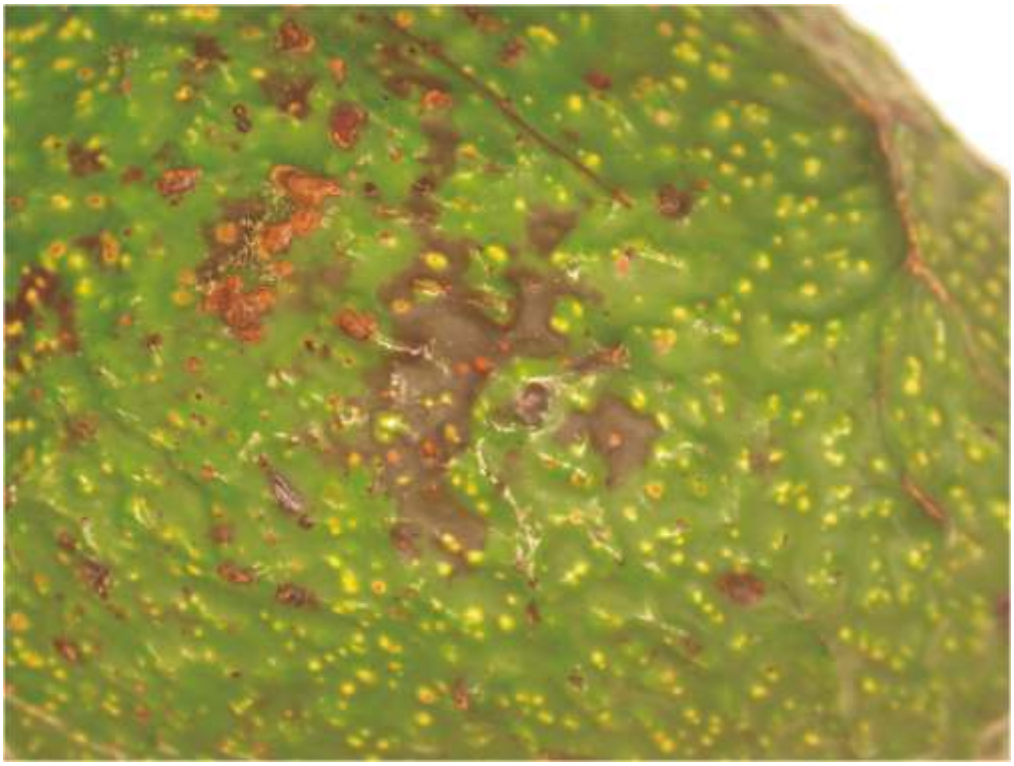

Figure 5. Early stage in the development of Discrete patches on the skin of a 'Hass' avocado fruit after 14 days at 2°C, harvested in February from Orchard B.

Figure 6. Discrete patches on 'Hass' avocado fruit after storage for 28 days at 1°C , harvested in February from Orchard A.

Table 2. Severity and Incidence of chilling disorders and fuzzy patches of late season 'Hass' avocado fruit harvested 9/2/2007 then stored for 14 or 28 days at low temperatures.

Disorder	Severity of Diffuse Flesh Discolouration (%)				Incidence of Diffuse Flesh Discolouration (%)			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	0.1	0.1			0.5	0.6		
Temperature								
1°C	0.0	0.0	1.3	1.1	0.0	0.0	4.0	4.0
2°C	0.0	0.0	0.9	1.2	0.0	0.0	3.0	6.0
3°C	0.2	0.1	0.0	0.6	1.0	1.0	0.0	3.0
4°C	0.0	0.0	0.4	0.3	0.0	0.0	3.0	3.0
5°C	0.0	0.0	1.2	0.2	0.0	0.0	6.0	2.0
Average	<0.1	<0.1	0.7	0.7	0.2	0.2	3.2	3.6

Disorder	Severity of Discrete patches (%)				Incidence of Discrete patches (%)			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	0.0	0.0			0.0	0.0		
Temperature								
1°C	1.6a	1.8a	29.6a	15.3a	11.0a	23.0a	92.0a	78.0a
2°C	0.8ab	0.9ab	9.6b	12.5a	7.0ab	13.0ab	47.0b	72.0a
3°C	0.5ab	0.3b	0.9c	1.9b	8.0a	4.0b	7.0c	14.0b
4°C	0.0b	0.1b	0.0c	0.0b	0.0b	1.0b	0.0c	0.0b
5°C	0.0b	0.0b	0.0c	0.3b	0.0b	0.0b	1.0c	2.0b
Average	0.6	1.1	8.0	6.0	5.2	8.2	29.4	33.2

Disorder	Severity of Fuzzy patches (%)				Incidence of Fuzzy patches (%)			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	0.0	0.0			0.0	0.0		
Temperature								
1°C	2.7	1.6a	2.9ab	3.4ab	69.0	63.0	34.0	52.0ab
2°C	1.2	1.4ab	3.8a	5.2a	47.0	63.0	61.0	76.0a
3°C	1.5	1.1ab	3.3ab	3.5ab	54.0	53.0	72.0	77.0a
4°C	0.9	0.8b	0.7b	1.6b	44.0	41.0	37.0	50.0b
5°C	1.2	1.0ab	1.1ab	1.7b	53.0	54.0	51.0	58.0ab
Average	1.5	2.4	1.6	3.1	53.4	51.0	54.8	62.6

Table 3. Severity and Incidence of chilling disorders and fuzzy patches of late season 'Hass' avocado fruit harvested 27/4/2007 then stored for 14 or 28 days at low temperatures.

Disorder	Severity of Diffuse Flesh Discolouration (%)				Incidence of Diffuse Flesh Discolouration (%)			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	0.0	0.0			0.0	0.0		
Temperature								
1°C	0.0	0.0	0.8	0.0b	0.0	0.0	1.0	0.0b
2°C	0.0	0.2	1.8	1.4b	0.0	2.0	2.0	4.0b
3°C	0.0	0.0	0.5	2.6ab	0.0	0.0	1.0	6.0b
4°C	0.1	0.0	1.5	6.9a	1.0	0.0	3.0	21.0a
5°C	0.0	0.5	1.4	2.8ab	0.0	1.0	3.0	10.0ab
Average	0.0	0.1	1.2	2.7	0.2	0.6	2.0	8.2

Disorder	Severity of Discrete patches (%)				Incidence of Discrete patches (%)			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	0.0	0.0			0.0	0.0		
Temperature								
1°C	0.4	0.5b	4.9a	6.1a	5.0	4.0	52.0a	50.0a
2°C	0.1	1.7a	3.3a	3.8ab	2.0	16.0	47.0a	36.0ab
3°C	0.2	0.5b	4.8a	5.6a	8.0	10.0	56.0a	49.0a
4°C	0.0	0.2b	0.7b	1.9b	0.0	5.0	9.0b	20.0b
5°C	0.0	0.0b	0.1b	1.1b	0.0	1.0	4.0b	14.0b
Average	0.2	0.6	2.8	3.7	3.0	7.2	33.6	33.8

Disorder	Severity of Fuzzy patches (%)				Incidence of Fuzzy patches (%)			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	<0.1	<0.1			1.0	4.0		
Temperature								
1°C	0.6ab	0.5	0.0	0.3	40.0ab	27.0a	4.0	14.0
2°C	0.9a	0.4	0.2	0.1	46.0a	25.0ab	5.0	4.0
3°C	0.6ab	0.3	0.0	0.2	33.0ab	18.0ab	1.0	11.0
4°C	0.7ab	0.1	0.3	0.0	35.0ab	8.0b	13.0	4.0
5°C	0.2b	0.3	0.3	0.3	13.0b	14.0ab	15.0	13.0
Average	0.6	0.3	0.2	0.2	33.4	18.4	7.6	9.2

The severity of brown patches of fruit harvested in February was greatest for fruit stored at 1°C and 2°C for Orchard A and at 1°C for Orchard B after 14 days storage duration (Table 4). After 28 days storage the severity of brown patches was very high, >35%, for all the fruit. The incidence of brown patches was very high for fruit from both orchards at 14 and 28 days storage duration and across all temperatures. The fruit harvested in April had lower severity of brown patches than the February harvested fruit (Table 5). Fruit from Orchard A had similar severity of brown patches across all temperatures and between the storage durations (Table 5). The fruit from Orchard B had greater

severity of brown patches than fruit from Orchard A with the fruit stored at 1°C having, in general, the greatest severity. The incidence of brown patches from Orchard A, although high, was lower than in the fruit from Orchard B (Table 5).

The severity and incidence of stem end rot for fruit from Orchard A harvested in February was not affected by storage temperature but was lower in fruit stored 28 days than fruit stored 14 days (Table 4). The fruit from Orchard B while having greater severity and incidence of stem end rot than fruit from Orchard B also were generally not affected by the storage temperature (Table 4). There was a trend for the fruit from Orchard B to have lower severity and incidence of stem end rot after 28 days storage than 14 days storage (Table 4). The fruit harvested in April had, in general, lower severity and incidence of stem end rot across both Orchard A and Orchard B than the fruit harvested in February (Tables 4 and 5). The fruit from Orchard A, harvested in April, had greater severity in stem end rot after 28 days storage than 14 days storage. The fruit stored at 1°C for 28 days from Orchard A had a significantly greater severity and incidence of stem end rot than the fruit stored at other temperatures (Table 5). The fruit from Orchard B stored at 1°C for 28 days had a significantly greater incidence of stem end rot than at other temperatures.

Table 4. Severity and Incidence of ripe fruit rots of late season 'Hass' avocado fruit harvested 9/2/2007 then stored for 14 or 28 days at low temperatures.

Disorder	**Severity of Brown Patches (%)**				**Incidence of Brown Patches (%)**			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	1.7	3.8			33.5	43.0		
Temperature								
1°C	25.1a	14.8a	66.9	46.0	78.0	75.0	98.0	97.0
2°C	24.3a	6.3b	51.1	42.0	62.0	65.0	90.0	94.0
3°C	4.3b	4.1b	47.0	36.7	35.0	46.0	77.0	94.0
4°C	5.5b	3.8b	59.6	50.9	29.0	49.0	90.0	92.0
5°C	5.9b	4.2b	45.7	36.6	52.0	43.0	86.0	91.0
Average	13.0	6.6	55.5	42.4	33.5	60.6	88.2	93.6

Disorder	**Severity of Stem end rot (%)**				**Incidence of Stem end rot (%)**			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	0.2	0.3			6.5	7.0		
Temperature								
1°C	0.8	5.9a	0.2	5.0a	20.0	69.0	9.0	57.0ab
2°C	1.3	5.7ab	0.3	3.1ab	38.0	71.0	11.0	73.0a
3°C	1.0	5.3ab	0.2	2.7ab	27.0	69.0	10.0	49.0ab
4°C	1.4	6.2a	0.2	2.1b	32.0	65.0	13.0	40.0b
5°C	0.8	3.4b	0.3	2.3ab	24.0	56.0	10.0	53.0ab
Average	1.1	5.3	0.2	3.0	28.9	66.0	10.6	54.4

Table 5. Severity and Incidence of ripe fruit rots of late season 'Hass' avocado fruit harvested 27/4/2007 then stored for 14 or 28 days at low temperatures.

Disorder	Severity of Brown Patches (%)				Incidence of Brown Patches (%)			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	1.2	1.8			19.0	33.0		
Temperature								
1°C	3.1	11.8a	6.5	17.3a	55.0	95.0a	74.0a	92.0a
2°C	4.3	5.3b	3.3	10.1b	75.0	74.0b	33.0b	73.0ab
3°C	3.4	6.1b	3.7	8.3b	58.0	82.0ab	52.0ab	78.0ab
4°C	3.0	12.2a	2.9	9.9b	62.0	79.0ab	51.0b	74.0ab
5°C	2.9	5.0b	4.0	7.4b	49.0	87.0ab	52.0ab	66.0b
Average	3.4	8.1	4.1	10.6	59.8	83.4	52.4	76.6

Disorder	Severity of Stem end rot (%)				Incidence of Stem end rot (%)			
Storage time (days)	14		28		14		28	
Orchard	A	B	A	B	A	B	A	B
Non-stored	0.1	0.1			5.0	5.0		
Temperature								
1°C	0.1	0.3	1.4a	2.1	5.0	20.0	32.0a	46.0a
2°C	0.1	0.2	0.8ab	1.6	5.0	7.0	16.0b	32.0ab
3°C	0.0	0.2	0.8ab	1.0	1.0	17.0	13.0b	28.0ab
4°C	0.1	0.2	0.3b	1.2	6.0	10.0	11.0b	29.0ab
5°C	0.1	0.1	0.4ab	0.8	4.0	5.0	8.0b	22.0b
Average	0.1	0.2	0.7	1.4	4.2	16.0	11.8	31.4

DISCUSSION

In this study the development of chilling injury symptoms on the skin of Hass avocado fruit was dependent on the storage temperature and duration. The minimum time the fruit took to develop discrete patches was 11 days at 1°C or 2°C with longer times needed at warmer temperatures. Avocado chilling injury is thought to be related to mass loss from the skin of about 6% at 2°C (Bower, 2005) and 6 to 8% at 5.5°C (Donkin and Cutting, 1994; Bower and Magwaza, 2004). This is a much greater mass loss than the fruit used in this experiment. The mass loss where discrete patches began to increase was about 2% occurring around 11 days. The reason for this difference between New Zealand and South African fruit is not known but highlights the need to control mass loss from late season fruit. The time taken for chilling injury symptoms to appear may be related to the proposed mechanism of how cold temperature affects the skin. The cold is considered to cause the cells in the skin to leak their contents, eventually the cells die and shrink then change colour (Platt-Aloia and Thomson, 1992). This is the discrete patches seen on the skin. The different stages of development of chilling injury can be seen in the photos above where the damaged area becomes sunken and more transparent over time. Eventually large areas of the fruit can be affected with damaged areas.

The time of year when the fruit are harvested could also affect the susceptibility of the fruit to developing chilling injury where fruit harvested in February had greater chilling injury symptoms than fruit harvested later in April. The April harvested fruit were considered to be more mature than the

February harvested fruit as their ripening times were faster by about two days. This is an observation not reported before on Hass avocado fruit grown in other countries. Late season South African Hass avocados could be more susceptible to chilling injury than mid season fruit (Bower and Magwaza, 2004; Bower and Papli, 2006). Avocado fruit are harvested over a relatively long time period of several months. During this time the phenology cycle of the tree continues. In the late season period the key phenological event of flower induction and initiation occurs around February and March (Dixon *et al*., 2006). It is possible that there were differences in the hormone balances within the tree or different demands for mineral nutrients that may have increased the susceptibility of the fruit to chilling injury.

The fruit from each orchard had different susceptibility to developing chilling injury. Orchard differences in the expression of chilling injury could be related to pre-harvest factors such as concentration of calcium (Chaplin and Scott, 1980) or nitrogen and iron (Magwaza *et al.*, 2008) in the fruit. New Zealand grown Hass avocados appear to be less susceptible to internal chilling injury than chilling injury on the skin. This has been noted on South African Hass avocado fruit as well (Van Rooyen and Bower, 2003).

The fruit in this study developed high amounts of brown patches and stem end rots typical of late season fruit (Dixon *et al.*, 2004). The greatest amounts of ripe rots were, generally, at the lowest temperatures suggesting that there was damage to the tissue that increased the expression of ripe rots. Storage of late season New Zealand Hass avocado fruit below 4°C could be considered to carry a high risk of developing high levels of ripe rots when ripe. It is uncertain if the chilling injury symptoms increased the expression of ripe rots or were a separate but parallel process. The symptom fuzzy patches on the skin of the fruit can be regarded as an expression of fungal rots. The fuzzy patches assessment has been included in the same table as the chilling injury symptoms discrete patches. It was observed that the initial symptom of discrete patches was a type of fuzzy patch. In this study an absolute separation of fuzzy and discrete patches as having two different causes was not possible.

New Zealand grown Hass avocado fruit are susceptible to chilling injury when harvested in February which then declines again so that April harvested fruit have a low susceptibility to chilling injury. This pattern is not the same as reported from South Africa where the fruit have a reduced susceptibility to chilling injury late season (Toerien, 1986). Shipping late season Hass avocados at low temperatures carries the risk of the fruit developing chilling injury symptoms when harvested in February. The risk of chilling injury reduces again by April when low storage temperatures may again be suitable. Chilling injury risk is related to the storage duration where the fruit appear to be able to tolerate a short period of low temperature. If the fruit only need to be stored for two weeks then temperatures below 4°C could be used providing ripe rots could be controlled.

CONCLUSIONS

Hass avocado fruit harvested in February have a high risk of developing chilling injury at temperatures below 4°C when stored for 28 days. When harvested in April the risk of chilling injury is greatly lower than for the February harvested fruit and storage below 4°C may be possible.

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