

Intra-seasonal variation in the ripening rates of South African avocados stored at different temperatures

FJ Kruger and D Lemmer

Lowveld Postharvest Services
PO Box 4001, Nelspruit 1200, SOUTH AFRICA
E-mail: fjkruiger58@gmail.com

ABSTRACT

During 2014, a set of storage trials were performed with the 'Hass' and 'Maluma' cultivars. It was noticed that on certain dates the 'Hass' fruit stored at the lower storage temperature settings ripened at faster rates than those stored at higher temperature settings. During 2015 we analysed all our databases of similarly structured trials conducted during the last decade. A number of similar cases were found where the fruit ripened faster after being stored at lower temperature settings, as opposed to higher settings. We hypothesise that the observed trends may possibly correlate with the carbohydrate and phenological cycles of the tree and the ripening related energy requirements of the fruit. In order to maximise the ripening potential of the fruit, we recommend that exporters step to the lowest possible temperature as soon as possible after packing and that they remain at this temperature until the fruit are ripened. It is also recommended that CA be applied as soon as possible after cooling and that it is kept in place for as long as possible during storage.

INTRODUCTION

During 2014, a trial was performed, aimed at comparing the black cold damage susceptibility of the 'Maluma' cultivar with that of 'Hass' (Lemmer & Kruger, 2015). To do this, samples of fruit from 'Maluma' and 'Hass' orchards were collected on three dates during the season and stored at four temperature settings. In addition to black cold damage, a number of other quality related readings were taken. This included the external colour development and ripening rates of the fruit. The observation was made that on two of the dates, fruit stored at the lower temperature settings (2-4°C) ripened faster than those stored at the higher settings (5-6°C).

The above observations prompted us to thoroughly review the ripening related aspects recorded by Magwaza *et al.* (2008); Magwaza *et al.* (2009) and Van Rooyen & Bezuidenhout (2010) during their studies on black cold damage. The present report deals with ripening rate trend interpretations made from the above investigations.

MATERIALS AND METHODS

The following information regarding the above mentioned studies is summarised in Table 1:

- The cultivars involved,
- The number of sampling dates,
- The periods from the first to the last sampling dates,

- The temperature settings used in each study.

With the exception of Van Rooyen and Bezuidenhout (2010), the original data sets were used to determine the ripening rates of the fruit. In the case of Van Rooyen and Bezuidenhout (2010), the bar charts published by the authors were carefully measured and the relative ripening rates calculated. In all cases the ripening rates were expressed as ratios of one another, the treatment that took the longest to ripen being 100%.

RESULTS AND DISCUSSION

'Hass' black cold damage study conducted by Lemmer & Kruger (2015)

The relative ripening rates of the fruit are depicted in Figure 1. The photos clearly show that, on 16 April and 21 May, the fruit stored at the lower temperature settings ripened faster than those stored at the highest setting. The opposite was true for the sample collected on 2 June.

'Pinkerton' black cold damage study performed by Magwaza *et al.* (2009)

The relative ripening rates are shown in Figure 2. In each case, the slowest ripening sample was designated a score of 100% and the other treatments expressed as relative values.



Table 1. Particulars of the various studies referred to in the present report.

Study	Cultivar	Sampling		Storage	
		No of dates	Period	No of temperature settings per date	Temperatures
Lemmer & Kruger 2015	'Hass'	3	16 Apr '14 - 3 Jun '14	4	2°C: last 2 dates 3°C: all 3 dates 4°C: all 3 dates 5°C: all 3 dates 6°C: 1st date only
Magwaza <i>et al.</i> (2008)	'Fuerte'	11	11 Apr '06 - 18 Jul '06	3	2°C: all 11 dates 5°C**: all 11 dates 7°C: all 11 dates
Magwaza <i>et al.</i> (2009)	'Pinkerton'	4*	28 May '08 - 16 Jul '08	2	2°C: all 4 dates 4°C: all 4 dates 6°C: all 4 dates
Van Rooyen & Bezuidenhout (2010)	'Hass'	3	2 Jun '09 - 17 Aug '09	2	1°C: all 3 dates 5.5°C: all 3 dates

* The original study refers to 5 dates. However, the 5th storage period was 10 days only (opposed to one month for the first 4 dates) and has thus not been included.

** In the publication the temperature is indicated as 4°C. However, subsequent reviews of the temperature loggers have revealed that the mean temperature in most of the cold room space was actually closer to 5°C during the original study period.

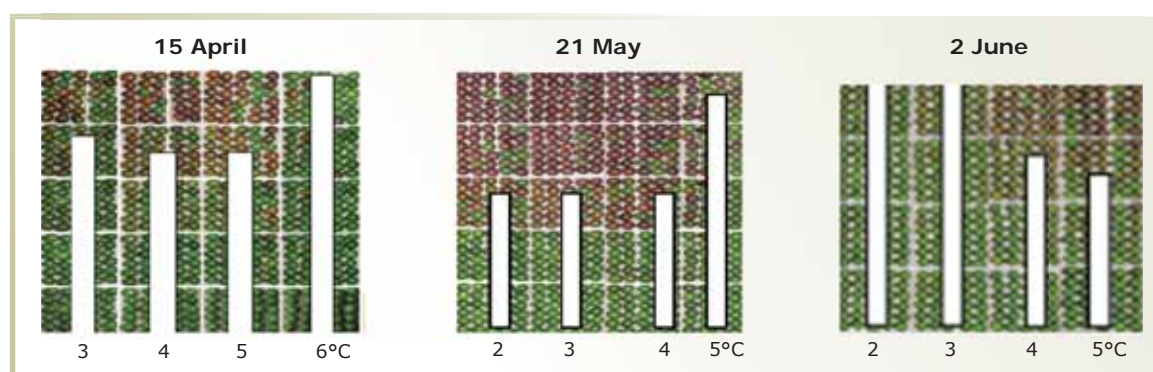


Figure 1. Ripening patterns of 'Hass' fruit stored at different temperature settings during the 2014 season (Lemmer & Kruger 2015).

From the graphs it is clear that, during the first and last dates (28 May and 16 July), the fruit stored at the lowest temperature setting (2°C) took longest to ripen. However, during the two middle dates (18 June & 3 July), the fruit stored at the highest temperature setting (6°C) took significantly longer to ripen than those stored at the two lower temperature settings.

'Hass' phytosanitary treatment study performed by Van Rooyen & Bezuidenhout (2010)

The relative ripening rates of the fruit are shown in Figure 3. On 2 July and 17 August the ripening rates of the samples stored at the two temperature settings only varied by approximately 8-12%. However, in the case of the sample taken on 2 July, the fruit stored at 1°C ripened at approximately twice the rate of those stored at 5.5°C.

Relating the above three studies' ripening trends with climate and pre-harvest horticultural practices

The scheduling of the first three studies in terms

of picking week is shown in Figure 4. In each case, an attempt was made to correlate the storage temperature dependent ripening rates of the fruit with a range of climatic and horticultural management variables. These included rainfall, daily minimum/maximum temperatures, irrigation and fertiliser practices, as well as the fruit maturity at time of harvest. We were unable to identify a specific factor/set of factors that seemed to significantly impact the storage temperature dependent ripening rates of the fruit.

'Fuerte' black cold damage study performed by Magwaza *et al.* (2008)

The relative ripening rates recorded in the above study are shown in Figure 5. In this case, the rates of the two higher storage temperature settings (5°C & 7°C) were pooled and compared with that of the 2°C rate. Unlike the trials conducted with 'Hass' and 'Pinkerton', the ripening rate of the 'Fuerte' fruit stored at 2°C never exceeded those of the higher temperature settings. However, the combined ripening rate of the higher settings undulated in a sinusoid manner in



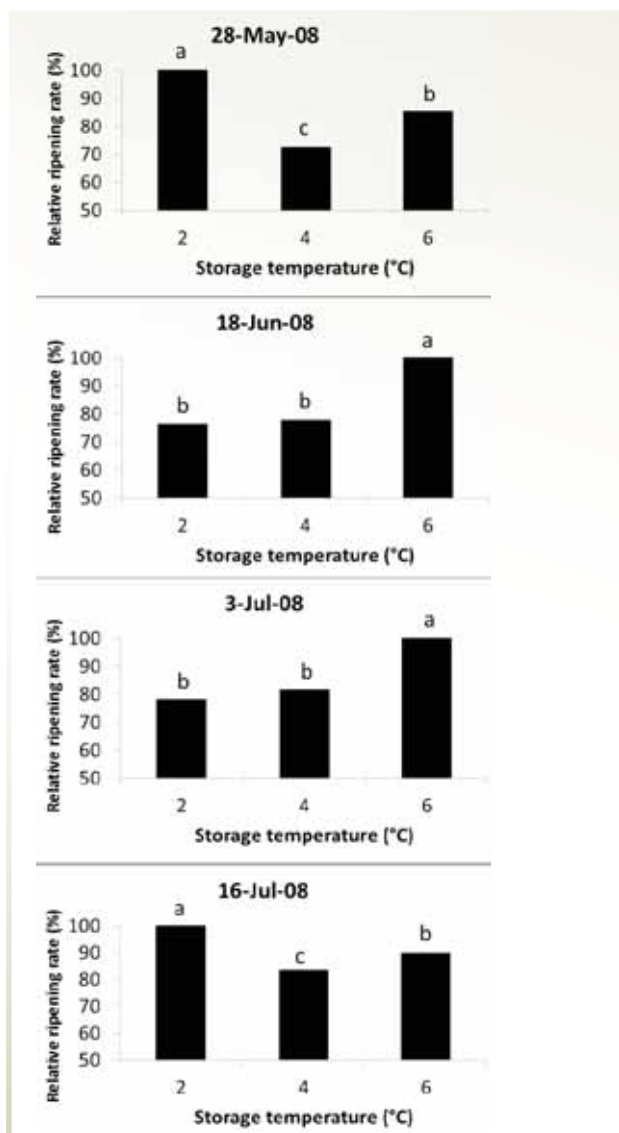


Figure 2. Relative ripening rates of 'Pinkerton' fruit stored at three temperature settings during the 2008 season. On each date, the slowest ripening sample was designated a score of 100% and the faster ripening treatments expressed as a percentage thereof.

relation to the 2°C setting. Peaks occurred during April and June and through during May and July.

Formulation of a research hypothesis

Based on the cyclical nature of the results, it would appear that the periods when the fruit stored at lower temperatures ripened faster than those stored at higher temperatures, may possibly correlate with the carbohydrate related phenological cycle of the tree (Fig. 6). A number of avocado carbohydrate metabolism related studies have been performed in different parts of the world. (It would appear that monosaccharides, from *de novo* synthesis/catabolisation of starch reserves, are transported to the fruit where they may serve as an energy source or be converted to starch and/or oil. The starch may then again be converted back to monosaccharides which may take additional time). The present authors, however, aim to focus on the industrial implications of the present

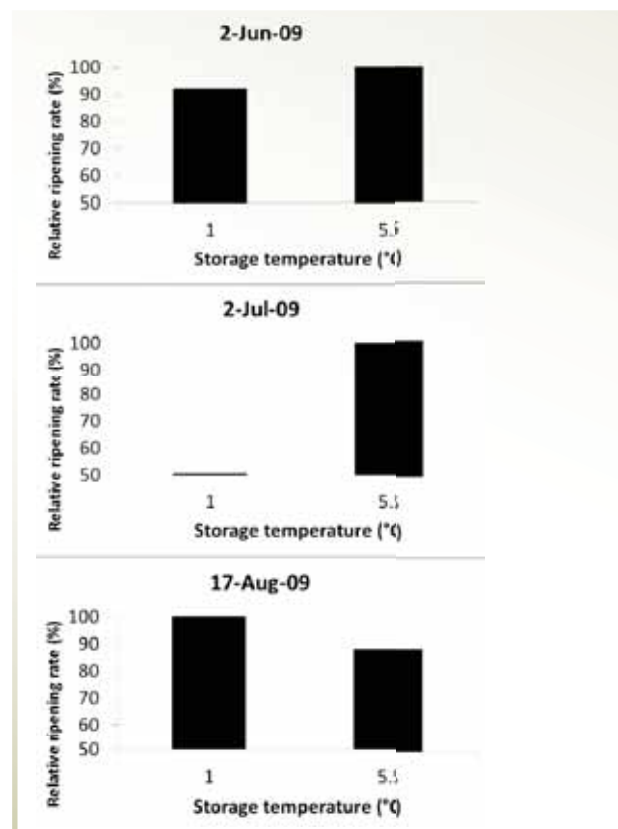


Figure 3. Relative ripening rates of three batches of 'Hass' fruit. (Deduced and interpreted from the graphs published by Van Rooyen and Bezuidenhout [2010]).

results, rather than the biochemical clarification of the processes involved.

As the composition and concentrations of available carbohydrate reserves in the fruit may vary from one year to the next (Fig. 7), the effect that storage temperature have on ripening may thus also vary. It may be possible that the relative ripening periods of fruit stored at higher temperature settings are more susceptible to variations in carbohydrate/energy fluctuations than those stored at lower temperature settings.

In most of the above (black cold damage related) studies, the sampling and ripening conditions were not kept constant and a fair amount of variation occurred in terms of sampling procedures, travel times and ripening temperatures. This is the reason why the ripening results are expressed as ratios. However, if the above energy availability hypothesis is correct, then variations in the ripening period should manifest as more pronounced variations at the higher storage temperatures, compared with the lower temperatures. The 'Pinkerton' trial conducted by Magwaza *et al.* (2009) gave the most consistent results insofar as this aspect is concerned. (This is possibly because 'Pinkerton' is known to have a low metabolic rate [Lemmer & Kruger, 2011]; the fruit for the trials were sampled from the same set of trees on each date and the orchard was close to the laboratory, thus minimising the effect that temperature fluctuations during harvest had on the post-storage



Picking week no	'Pinkerton' (Magwaza <i>et al.</i> 2008)	'Hass' (Van Rooyen & Bezuidenhout 2010)	'Hass' Lemmer & Kruger 2015)
16			<p>15 April</p>
17-20			
21			<p>21 May</p>
22	<p>28-May-08</p>		
23		<p>2-Jun-09</p>	<p>2 June</p>
24			
25	<p>18-Jun-08</p>		
26			
27	<p>3-Jul-08</p>	<p>2-Jul-09</p>	
28			
29	<p>16-Jul-08</p>		
30-33			
34		<p>17-Aug-09</p>	

Figure 4. Scheduling of the previous three studies according to picking week.



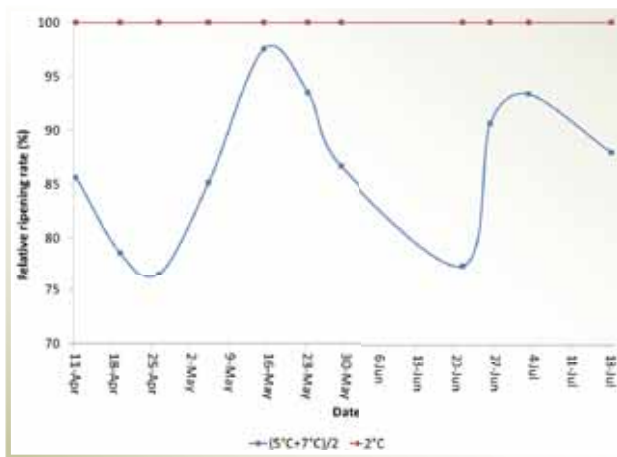


Figure 5. Relative ripening rates of 'Fuerte' avocado fruit during the 2006 season. The ripening rates of the 2°C treatment is expressed as 100% while the means of the 5°C + 7°C treatments are expressed as a proportion thereof.

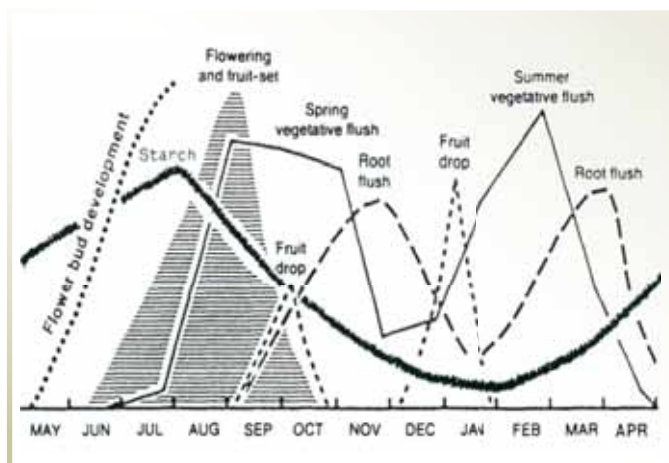


Figure 6. Avocado phenological chart by Whiley and Wolstenholme (1990).

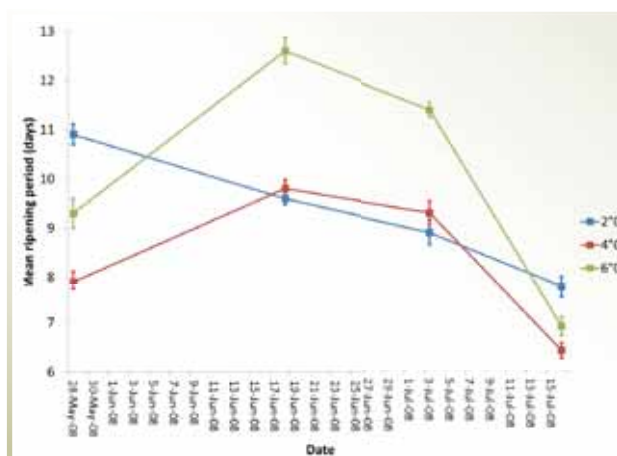


Figure 8. Mean ripening periods recorded for 'Pinkerton' fruit stored at three temperature settings during the 2008 season.

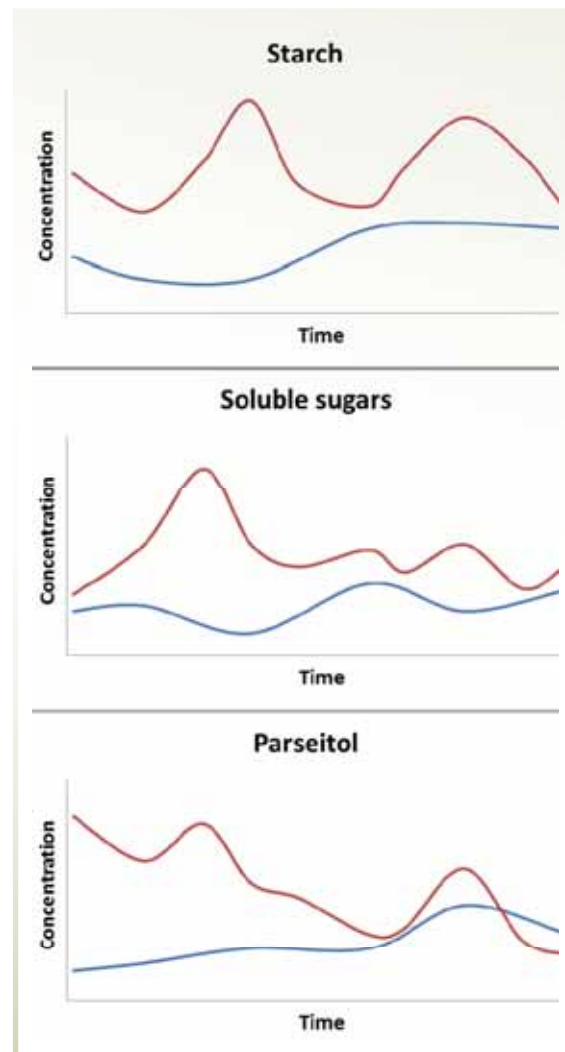


Figure 7. Schematic representations of variations in the starch, soluble sugar and parseitol content of 'Hass' fruit sampled during two separate seasons in New Zealand. The schematic representation is based on the graphs published by Burdon *et al.* (2007).

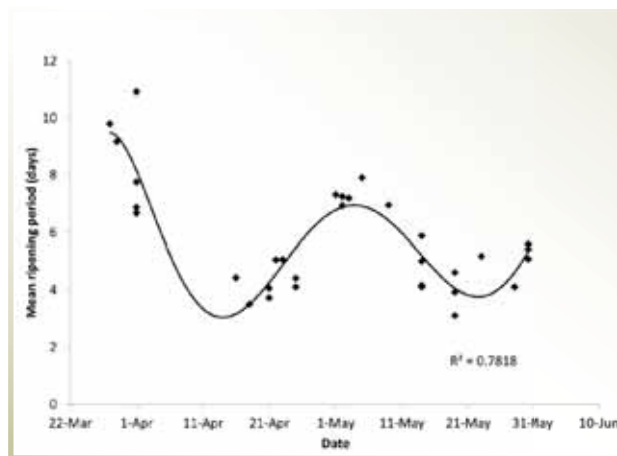


Figure 9. Ripening patterns of 'Pinkerton' fruit from a holdback sample programme during the 2014 season.



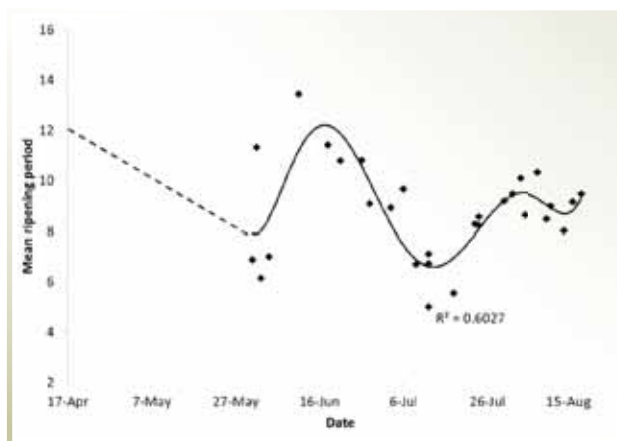


Figure 10. Ripening patterns of 'Hass' fruit from a holdback sample programme during the 2011 season.

ripening patterns). In Figure 8, it is shown that the mean ripening period of the 2°C treatment reduced in a maturity related linear fashion from a mean of about 11 days by the end of May to a mean of just under 8 days by middle July. In contrast, the mean ripening period of the 6°C treatment increased from just over 9 days on 28 May to twelve and a half days on 18 June. It then decreased to 11.4 days on 3 July and was 7 days by 16 July. The 4°C treatment showed a similar increase in ripening period during the two middle dates, but the variation was smaller. Interestingly, the 4°C treatment's mean ripening periods remained less than those of the 6°C period, even on the first and last dates when both the 4°C and 6°C treatments were lower than that of the 2°C treatment.

Another avenue of research aimed at evaluating the present hypothesis involves the survey of

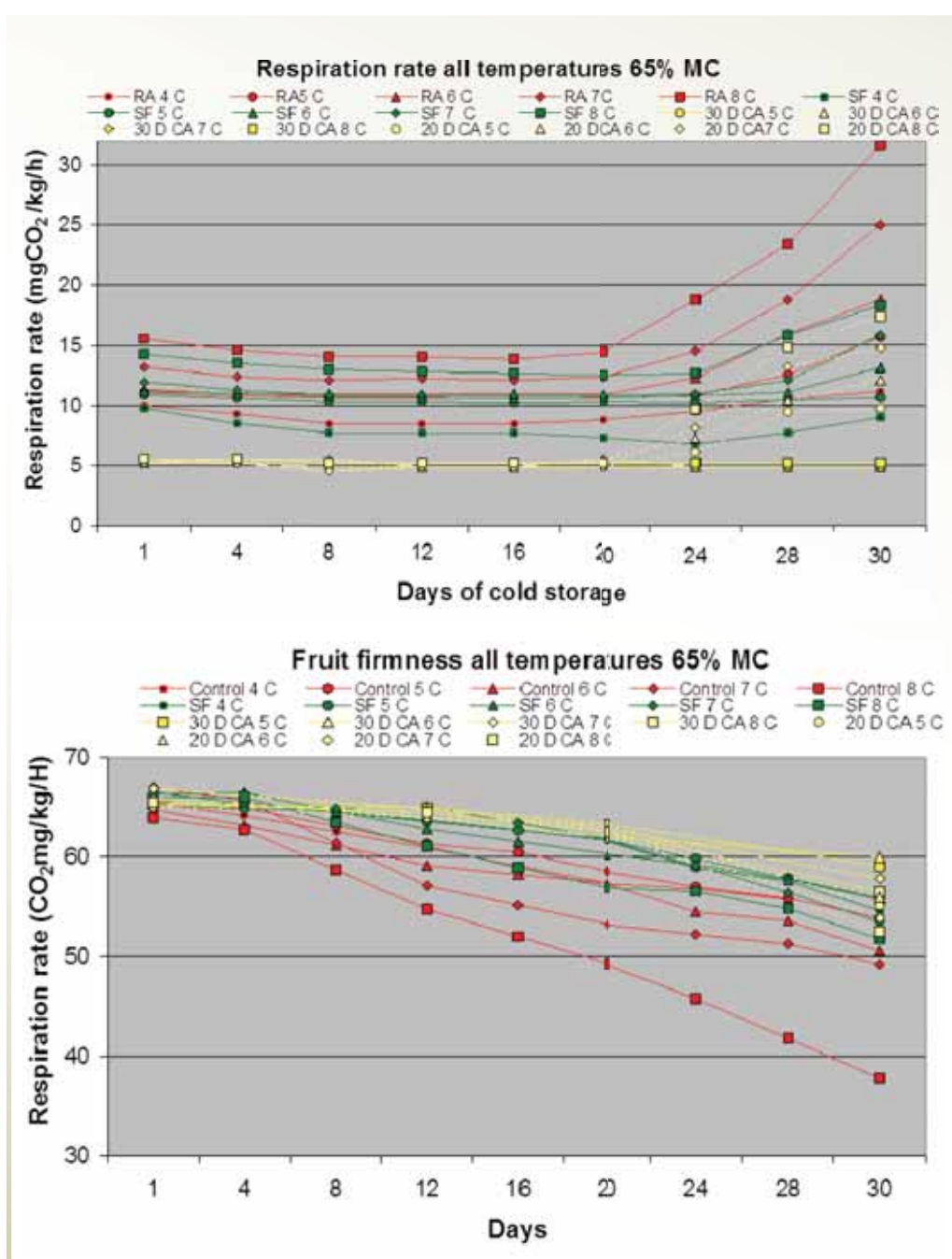


Figure 11. The firmness (bottom graph) of fruit stored at higher temperatures under RA conditions tends to start decreasing before the respiration rate starts to increase (top graph). This effect that the higher temperature settings had on the mean firmness of the above 'Hass' fruit samples was significantly reduced by the use of CA. The graphs are from Lemmer *et al.* (2010).



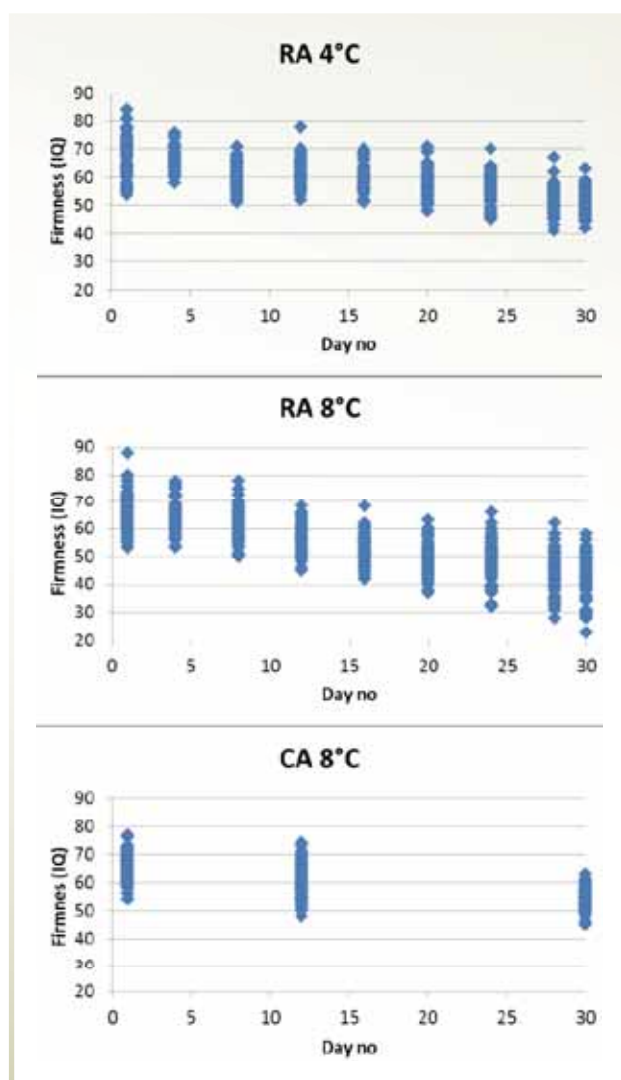


Figure 12. The firmness spread of fruit samples stored at higher temperatures under RA conditions tended to increase during a 30 day period. The divergence in firmness between individual fruit was significantly contained by the use of CA, even at relatively high temperature settings. The figures are based on data generated by Lemmer *et al.* (2010).

commercial holdback samples so as to establish whether periods of delayed ripening occurred during any part of the season. Analyses of holdback samples' ripening rates provided quite interesting results. The ripening rates of 'Pinkerton' fruit, as recorded by the current authors during the 2014 season, are shown in Figure 9. A maturity related reduction in ripening period occurred from the end of March until the middle of April. The ripening pattern then showed an undulating trend. Since five orchards were involved, the decrease in ripening rate was not orchard related. The holding temperature was 5-6°C. It is therefore quite possible that the increase may have been caused by the above mentioned physio-phenological factors. Another example, in this case of the 'Hass' cultivar during 2011, is shown in Figure 10. As holdback samples were only kept as from a relatively advanced maturity stage (MC < 70%), the graph does not show the beginning of the season's maturity

related decline in mean ripening period. The results did, however, show a similar undulating pattern.

From previous studies (Lemmer *et al.*, 2010) it would appear that one way of mitigating the effect of the above mentioned temperature induced variations is to employ CA storage. While RA fruit stored at a high temperature setting start to soften before the respiration rate starts to rise, this is not the case with CA fruit stored at a high temperature setting (Fig. 11). In addition, the variation in storage induced softening is also reduced by CA storage (Fig. 12).

RECOMMENDATIONS

- Step to the lowest possible temperature as soon as possible after packing and remain at this temperature until the fruit are ripened.
- Apply CA as soon as possible after cooling and attempt to keep it in place for as long as possible before ripening starts.

ACKNOWLEDGEMENTS

The authors would like to thank SAAGA for funding the project and Mark Penter for editing the manuscript.

REFERENCES

- BURDON, J., LALLU, N., HAYNES, G., PIDAKALA, P., WILLCOCKS, P., BILLING, D., MCDERMOTT, K., VOYLE, D. & BOLDINGH, H. 2007. Carbohydrate status of late season 'Hass' avocado fruit. *New Zealand Avocado Growers' Association Annual Research Report* 7: 97-102.
- LEMMER, D. & KRUGER, F.J. 2011. Respiration and softening rates of 'Fuerte' and 'Pinkerton' avocados and the effect that cold chain breaks have on the ripening and quality of these cultivars. *South African Avocado Growers' Association Yearbook* 34: 26-34.
- LEMMER, D. & KRUGER, F.J. 2015. Comparison of the black cold damage sensitivity and ripening uniformity characteristics of the 'Maluma' and 'Hass' avocado cultivars. *South African Avocado Growers' Association Yearbook* 38: 19-26.
- LEMMER, D., MALUMANE, T.R. & KRUGER, F.J. 2010. Effect of cold chain breaks on the ripening and quality of 'Hass' avocados. *South African Avocado Growers' Association Yearbook* 33: 14-23.
- MAGWAZA, L.S., LEMMER, D., NTANDANE, J. & KRUGER, F.J. 2008. Effect of N and Fe fertilizer treatments on the incidence of chilling injury in 'Fuerte' and 'Hass' avocados. *South African Avocado Growers' Association Yearbook* 31: 7-9.
- MAGWAZA, L.S., NTANDANE, M.J. & KRUGER, F.J. 2009. Follow-up study on the effect that iron supplements have on the postharvest chilling injury disorder of avocado fruit. *South African Avocado Growers' Association Yearbook* 32: 13-17.
- VAN ROOYEN, Z. & BEZUIDENHOUT, J. Semi-commercial trials to determine the risk of shipping South African 'Hass' at 1°C. *South African Avocado Growers' Association Yearbook* 33: 27-31.
- WHILEY, A.W. & WOLSTENHOLME, B.N. 1990. Carbohydrate management in avocado trees for increased production. *South African Avocado Growers' Association Yearbook* 13: 25-27.

