Four increasingly important physiological disorder variants of South African 'Hass' avocado fruit

FJ Kruger and D Lemmer

Lowveld Postharvest Services,
PO Box 4001, Nelspruit 1200, SOUTH AFRICA
E-mail: fjkruger58@gmail.com

ABSTRACT

This report deals with four 'Hass' avocado physiological disorder variants we respectively refer to as "storage induced internal chilling injury", "late season black cold damage", "extended storage induced black cold damage" and "poor/mottled external colouration". "Storage induced internal chilling injury" bears a resemblance to mild orchard freeze damage. However, instead of being caused by low orchard temperatures, it only develops during storage. "Late season black cold damage" is a black cold damage variant that occurs during the late season. It would appear that both these disorders are most prevalent in late set 'Hass' fruit. However, the shape and size of the fruit differs. "Storage induced internal chilling injury" occurs in small round fruit while the "late season black cold damage" affected fruit are pear shaped and within the normal size distribution range. "Storage induced internal chilling injury" affected fruit would further appear to be from malnourished trees as they have lower concentrations of most mineral elements. "Extended storage induced black cold damage" develops during prolonged storage and subsequent ripening. This contrasts with normal black cold damage which develops during the early stages of storage. "Extended storage induced black cold damage" affected fruit would further appear to be particularly susceptible, even at relatively high storage temperatures. When stored at these higher temperatures they only start to develop the symptoms after an extended storage period. Based on our initial observations we hypothesise that this increased sensitivity may be caused by incessant cloudy conditions prior to harvest. In so far as "poor/mottled colouration" is concerned, our preliminary observations indicate that a relationship exists between "poor colouration" and high minimum temperatures prior to harvest. In the case of "mottled colouration" it would appear that the de-greening process was hampered by the above mentioned "late season black cold damage" lesions.

INTRODUCTION

This study concerns two South African Avocado Growers' Association (SAAGA) funded projects, namely:

- The utilisation and refinement of the currently used moisture content based maturity determination procedure.
- Processing of existing databases from the SAAGA overseas technical officer (OTO), export organisations, packinghouses, producers, service providers and research organisations.

The article deals with four physiological disorder variants of the 'Hass' variety we respectively refer to as "storage induced internal chilling injury", "late season black cold damage", "extended storage induced black cold damage" and "poor/mottled external colouration".

MATERIALS AND METHODS

Fruit moisture content analyses

During the 2015 season, moisture content analyses were performed of 'Hass' fruit from 151 orchards located on 17 of ZZ2's farms. Samples were taken at approximate 10 day intervals during the two month period prior to the anticipated harvest date. The analyses were performed according to the standard PPECB method used by the industry.

OTO database analyses

The current OTO's records for the period 2001 to 2013 were obtained. The incidences of the four physiological disorders referred to above were plotted on a weekly basis for the above seasons. Annual variation in the prevalence of the disorders was then correlated with the climatic conditions prevailing at the time.

Exporter feedback enquiries

Exporters' feedback reports contain valuable data that can be processed into useable information, especially when orchard practice and microclimate data sets from individual farms are also available.

Research databases
The current researchers have a postharvest database for the period 1995 to 2014. This is regularly used for cross referencing the industry generated data sets.

RESULTS AND DISCUSSION

"Storage induced internal chilling injury"
"Storage induced internal chilling injury" (Fig. 1) bears a resemblance to mild orchard freeze damage. However, the fruit never develops the severe symptoms associated with orchard freeze damage (Fig. 2). Also, unlike orchard freeze damage, which is already present before harvest, "storage induced internal chilling injury" only develops during storage. During the last number of seasons this disorder has become increasingly prevalent during the early season, especially in a group of orchards located northwest of Tzaneen (Fig. 3). Producers in this area suffered significant financial losses due the disorder.

"Late season black cold damage"
Classical black cold damage (Fig. 4) is an external disorder affecting South African avocado exports on an annual basis. When subjecting fruit from a single orchard to chilling inducing storage temperatures, it becomes clear that the disorder is generally most prevalent at the beginning of the season (Fig. 5).

As the name indicates, "late season black cold damage" is a black cold damage variant. The SAAGA overseas technical officer reported that, during certain years, the disorder is more prevalent (on an industry basis) during the mid to late season. A good example is the 2004 season when the incidence of the disorder dramatically increased towards the end of the season (Fig. 6). This observation was corroborated by Lemmer *et al.* (2005) who noticed a similar trend in specific 'Hass' orchards in the Kiepersol area during 2004 (Fig. 7). Observations made during the current season indicated that the lesions are generally smaller and more diffuse (Fig. 8) than those usually associated with black cold damage.

Figure 1. "Storage induced internal chilling" symptoms in 'Hass' fruit from the Tzaneen area.

Figure 2. "Orchard freeze damage" symptoms of increasing intensity in longitudinally and cross sectioned avocado fruit.

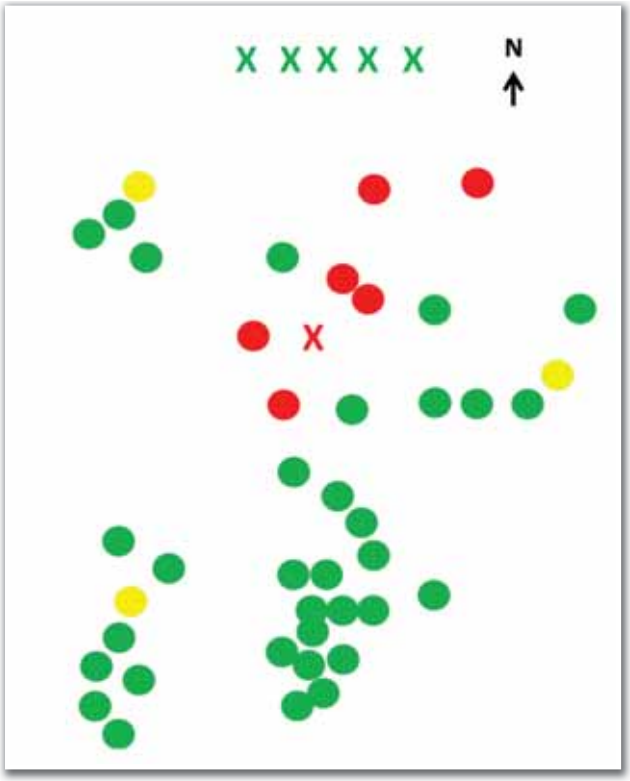

Figure 3. Spatial distribution of "storage induced internal chilling injury" (circles) and "late season black cold damage" (crosses) in 'Hass' fruit from two producers/exporters in a production area northwest of Tzaneen. Red signifies a high prevalence; green an absence and yellow a low incidence/intensity of the disorders. The row of green crosses at the top of the figure indicates that the greater majority of orchards of the specific producer was located to the north of this area and was free of the "late season black cold damage" disorder.

Figure 4. Typical irregular shaped "black cold damage" symptoms on 'Hass' fruit.

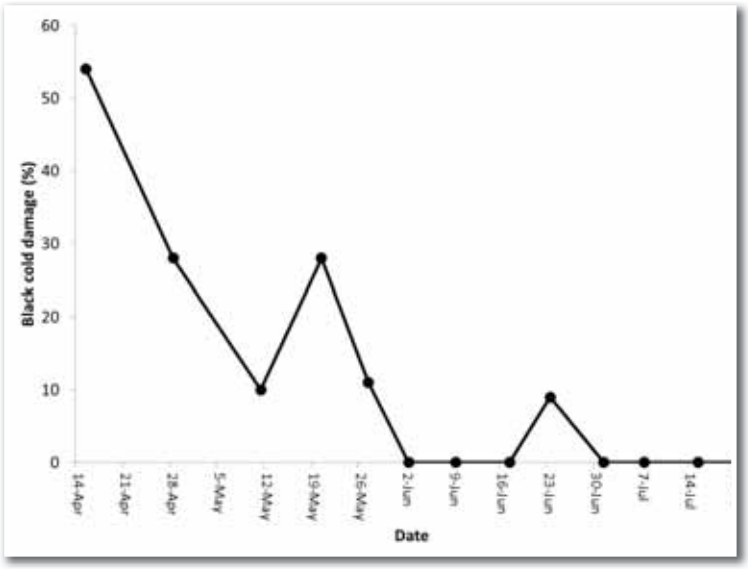

Figure 5. Familiar declining classical black cold damage incidence pattern of 'Hass' avocado fruit from an orchard in the Kiepersol area during the 2004 season.

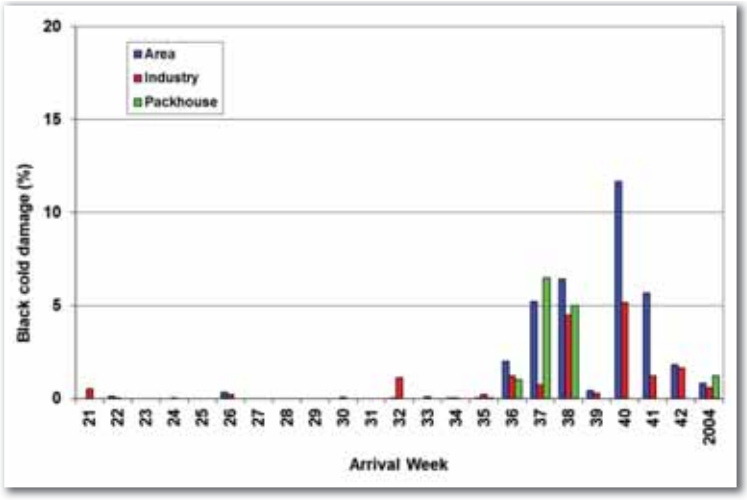

Figure 6. Increase of black cold damage symptoms towards the end of the season during 2004. The area referred to is Tzaneen and the green bars represent an example of the prevalence at one of the pack houses in the area.

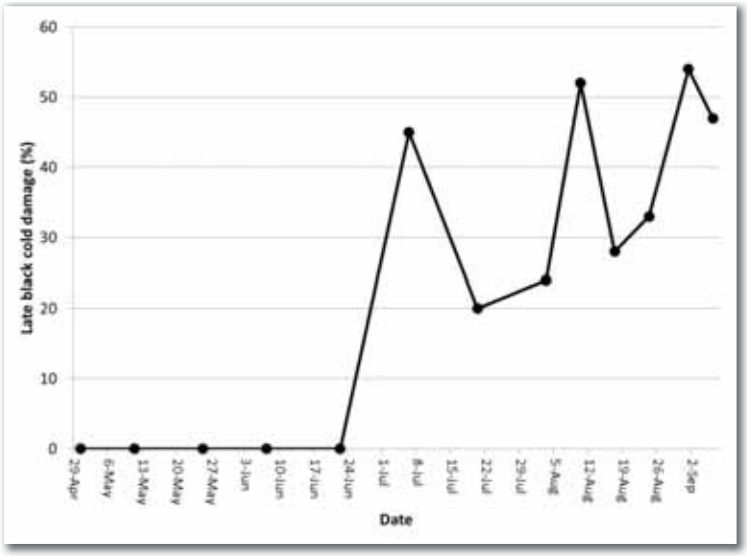

Figure 7. Development of "late black cold damage symptoms" in a single orchard in the Kiepersol area during the 2004 season.

Possible relationship between "storage induced internal chilling injury" and "late season black cold damage"

In order to determine whether a maturity related association exists between "storage induced internal chilling injury" and "late season black cold damage", the pulp moisture content of 153 'Hass' orchards located in the greater Tzaneen area was compared from middle February to middle May 2014 (Fig. 9). An attempt was made to correlate the maturation patterns of the different orchards with quality related feedback received from overseas importers. In general, the fruit moisture contents of the different orchards decreased at a relatively steady rate. However, at one location (Farm 7) there were indications that a late set came into play in a part of the orchard. These fruit were probably only included in the moisture content samples when they reached a size similar to those of the early sets (Kruger *et al*., 2014). Since there was a five percentage points difference in the moisture contents of two batches taken during packing (Fig. 10), it is possible that the less mature fruit were only present in part of the orchard. From present research being conducted on the topic (Mathaba *et al*., 2015) it would appear that the susceptible fruit were from the lower laying, colder sections of the affected orchards.

Interestingly, the above farm was situated in the middle of an area where the incidence of "storage induced internal chilling injury" was highest (Fig. 3). However, a definite difference in shape was noticed between the fruit affected by "late season black cold damage" and those afflicted by "storage induced internal chilling injury". The late season "black cold damaged" fruit had a normal pear shape while the "storage induced internal chilling injured" fruit were round. Preliminary mineral analyses of the fruit indicated that the round fruit had lower concentrations of virtually all mineral elements. Further enquiries revealed that the symptom was particularly prevalent in organic orchards, thus confirming the plant nutrition link.

At this stage we hypothesise that both "late season black cold damage" and "storage induced internal chilling injury" are most prevalent in late set fruit from orchards in which a late flowering was induced during the preceding season. Late set fruit are known to be more susceptible to black cold damage (Snijder *et al.*, 2002) and in the case of "storage induced internal chilling injury" the situation is exacerbated by inadequate plant nutrition practices.

"Extended storage induced black cold damage"
Most South African exporters and researchers' experience regarding black cold damage indicates that it develops relatively early during the storage period (Fig. 11). The OTO and exporters' data bases indicate that fruit landed in Europe without black cold damage are highly unlikely to develop the disorder during the subsequent distribution and ripening phases. However, during the last number of seasons a black cold-like symptom was noticed in 'Hass' fruit subjected to extended storage periods. Instead of

Figure 8. Diffuse "late black cold damage" symptoms on fruit from the orchard indicated with a red cross in Figure 3.

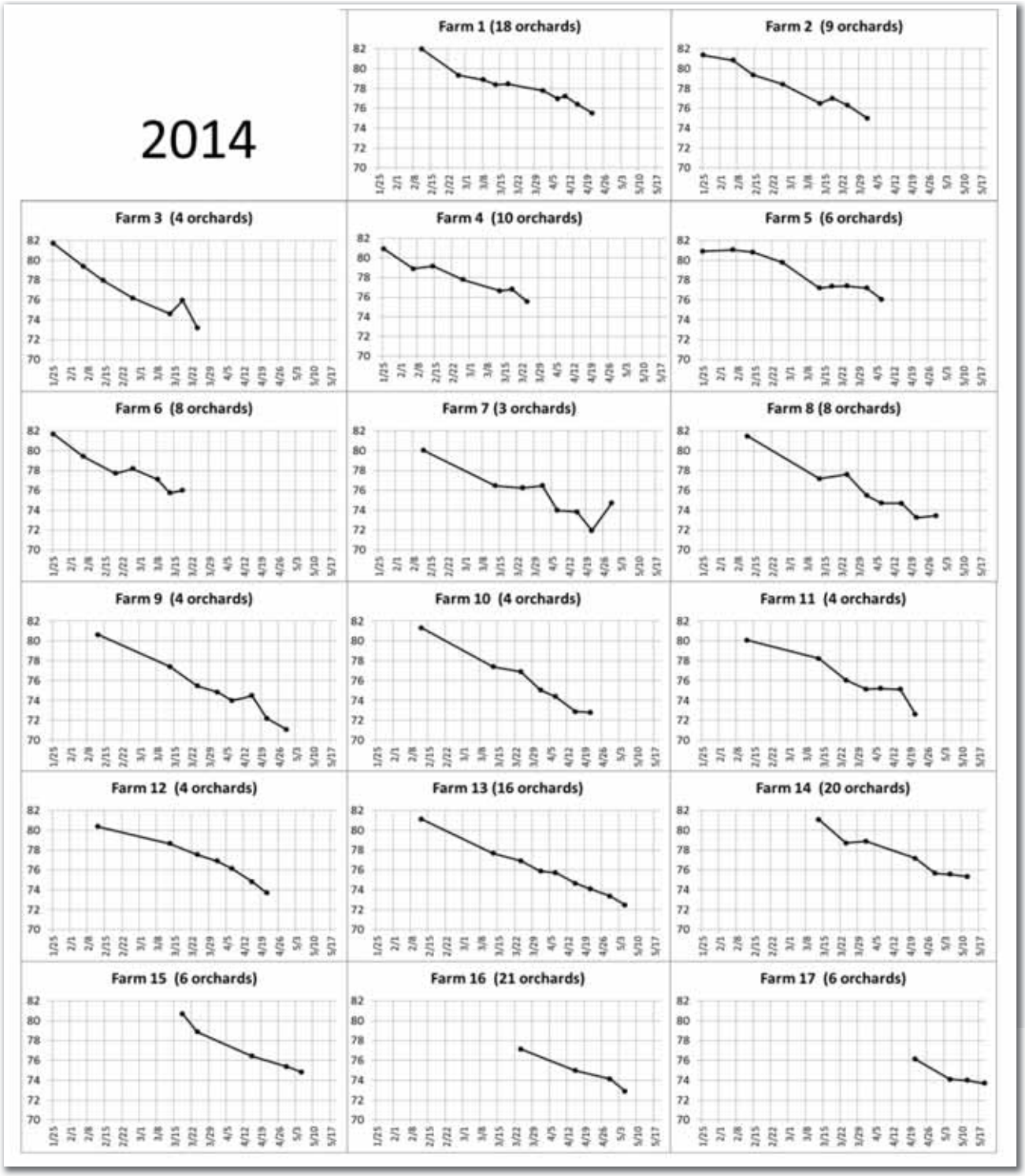

Figure 9. Maturation rates of 17 'Hass' orchards in the greater Tzaneen area during 2014. The horizontal axes represent the sampling dates and the vertical axes the fruit moisture contents as a percentage.

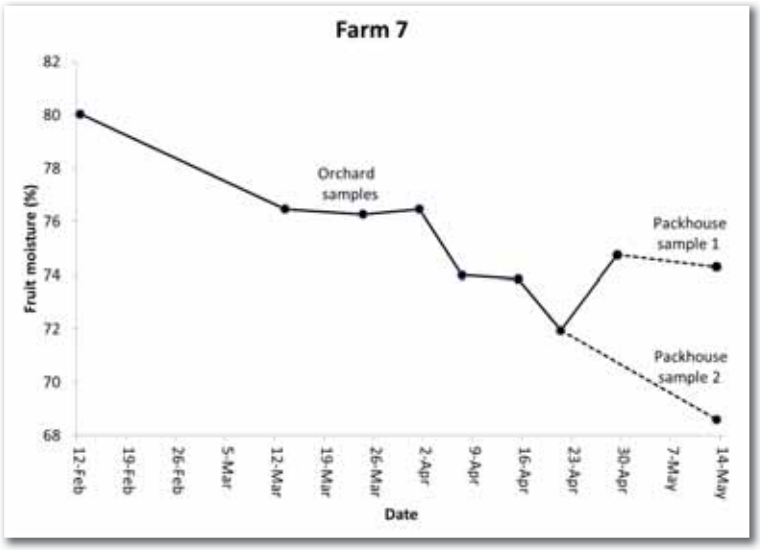

Figure 10. Maturation rate of one of the orchards on Farm 7 shown in Figure 9 which is also the orchard indicated with a red cross in Figure 3. Samples 1 and 2 were taken from different batches delivered to the pack house.

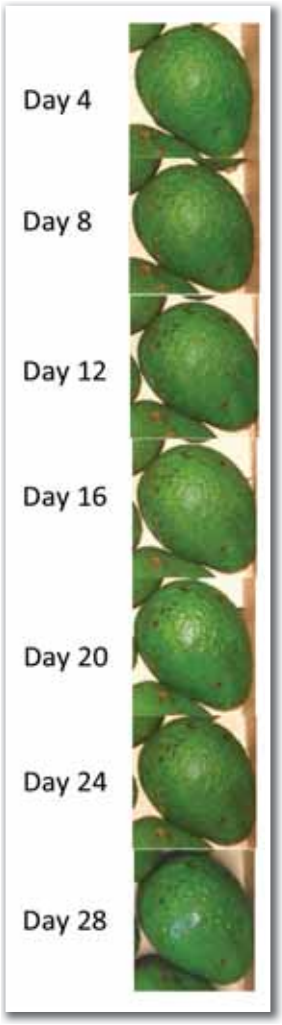

Figure 11. Black cold damage symptoms usually appear during the early stages of storage. They do not enlarge during storage and new lesions do not develop towards the end of the storage period.

Figure 12. "Extended storage black cold damage" symptoms that sometimes develop during cool storage after arrival in Europe.

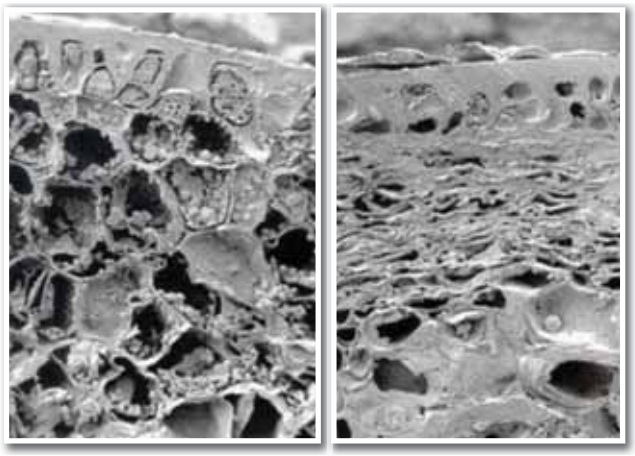

Figure 13. Scanning electron micrograph of intact avocado skin (left) and black cold damaged skin (right) which has lost its cell contents and became compacted.

the irregular shaped pattern usually associated with classical black cold damage, these fruit developed well defined symmetric lesions (Fig. 12) during prolonged storage periods or subsequent ripening.

Black cold lesions consist of layers of dead cells (Fig. 13). Since the contents of the cells have evaporated, the cells are compacted and the lesions have a sunken appearance. As the cells have died due to the low temperature conditions, high relative humidity conditions can only slightly reduce the rate of cell content evaporation and the subsequent emergence of lesions. However, with "extended storage induced black cold damage" ripeners claim that they can slow down the manifestation of the lesions by increasing the relative humidity in the ripening room.

"Extended storage induced black cold damage" would seem to be quite prevalent in fruit from certain East African 'Hass' producing regions. Fruit mineral analyses have showed that the fruit have a fairly similar mineral composition to South African avocado fruit of comparable maturity. As cloudy/rainy conditions prevail in these East African growing regions prior to harvest, we hypothesise that the disorder is exacerbated by inadequate "heat shock protein" induction in the fruit. These deductions may be supported by the fact that very low incidences of sunburn occur in these areas due to the cloudy conditions. However, it must be stressed that further research is required to confirm/refute this hypothesis.

"Poor / mottled external colour"

Due to a high prevalence of the disorder during the recent past, the OTO has started to record the annual incidences of poor external colour (Fig. 14) since the 2009 season (Fig. 15). A polynomial representation of the incidences of the disorder, as recorded

Figure 14. Ready to eat 'Hass' fruit with poor (left) and mottled (right) external colour development.

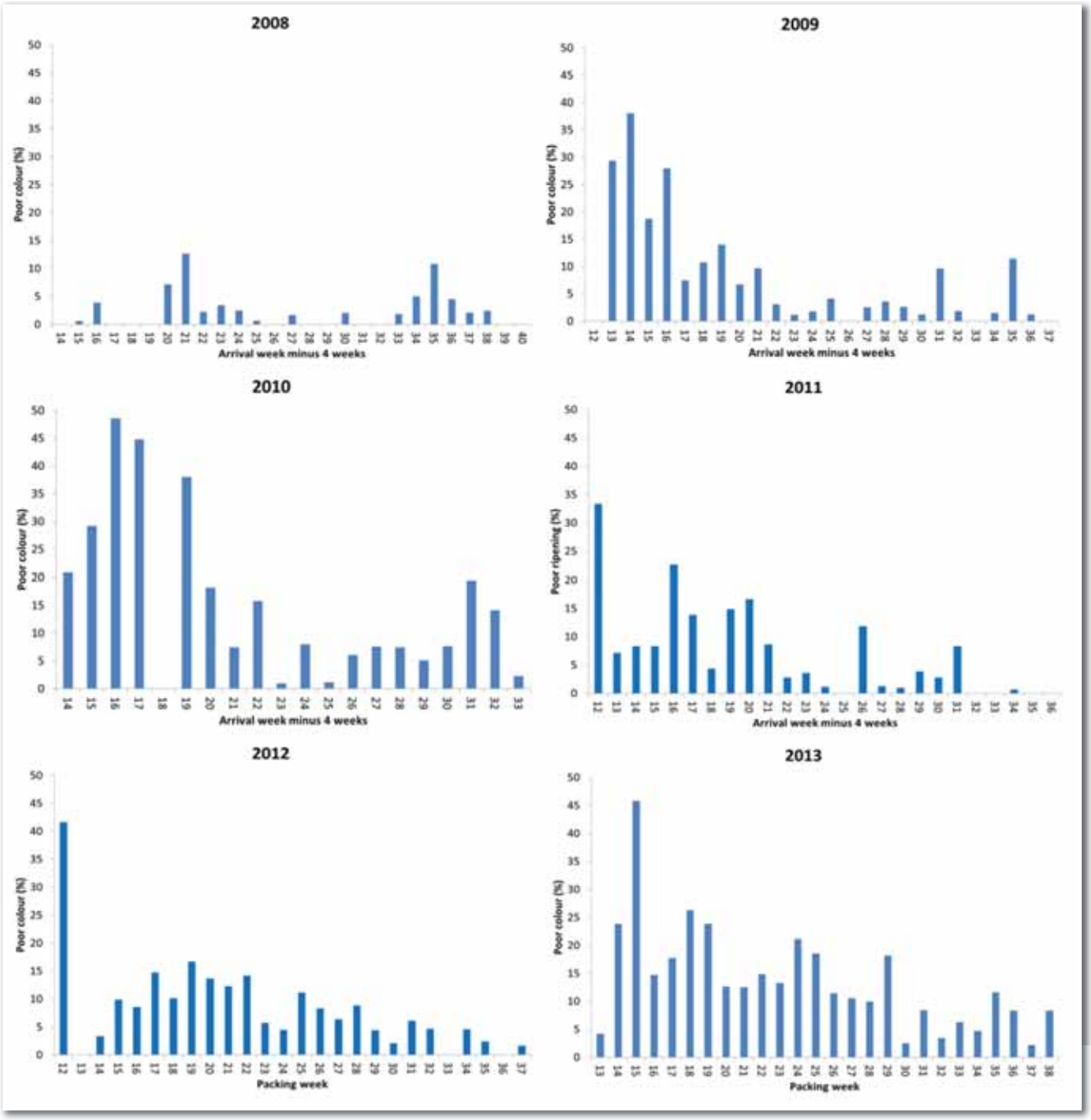

Figure 15. Poor colour in 'Hass' fruit as recorded by the OTO during the 2008 to 2013 seasons.

during four of the seasons, is shown in Figure 16. Since poor external colouration is associated with high orchard temperatures in the deciduous and citrus industries, the average weekly minimum temperature polynomials are also shown for each of the above years (Fig. 16). The "poor external colour" polynomials are based on data from all production regions starting with Levubu and ending with KwaZulu-Natal. In so far as the average weekly minimum temperature polynomials are concerned, data from one of the centrally located production regions (Nelspruit) were used.

For the sake of convenience, the seasons plotted in Figure 16 are referred to as the red, purple, green and blue seasons. The red season had the highest early season minimum temperatures and also the highest incidence of poor external colouration during the early season. The blue season was characterised by the lowest early season minimum temperatures and the lowest incidence of poor external colouration during the early season. The green and purple seasons were intermediate. When carefully examining the data it is interesting to note that during the early season, the "poor colour" trend lines are aligned with the corresponding mean weekly minimum temperature polynomials. This also applies to the midseason (i.e. the red season's increase in temperature and accompanying poor de-greening during weeks 24 to 30), as well as during the end of the season. Our preliminary observations would therefore indicate that a relationship exists between poor colouration and minimum orchard temperatures. The data, however, does not enable the establishment of threshold temperature values for the disorder. These will have to be determined under experimental conditions.

In the case of mottled colouration it would appear that "late season black cold damage" (Fig. 3) may be a contributing/confounding factor due to the de-greening process being interrupted by the diffuse patches of dead skin.

ACKNOWLEDGEMENTS

The authors would like to thank all producers, packinghouses and exporters who made their records available to the researchers. We are also indebted to Mark Penter of the ARC-ITSC who edited the manuscript.

REFERENCES

KRUGER, F.J., LEMMER, D., PIETERSE, P., STEYN, J. & NZANZA, B. 2014. Refinement of the currently used moisture content based maturity determination procedure. *South African Avocado Growers' Association Yearbook* 37: 30-34.

LEMMER, D., MALUMANE, T.R., NXUNDU, Y., TANDANE, J. & KRUGER, F.J. 2005. New advances in the development of quality assurance norms for the South African avocado export industry. *South African Avocado Growers' Association Yearbook* 28: 18-23.

MATHABA, N., MLIMI, J., NTANDANE, M.J., MAFEO, T.P. & KRUGER, F.J. 2015. Studies on the skin colour problem in 'Hass' avocado fruit during ripening. *South African Avocado Growers' Association Yearbook* 29: In press.

SNIDJER, B., PENTER, M.G., MATHUMBU, M.J. & KRUGER, F.J. 2002. Further refinement of 'Pinkerton' export parameters. *South African Avocado Growers' Association Yearbook* 25: 50-53.

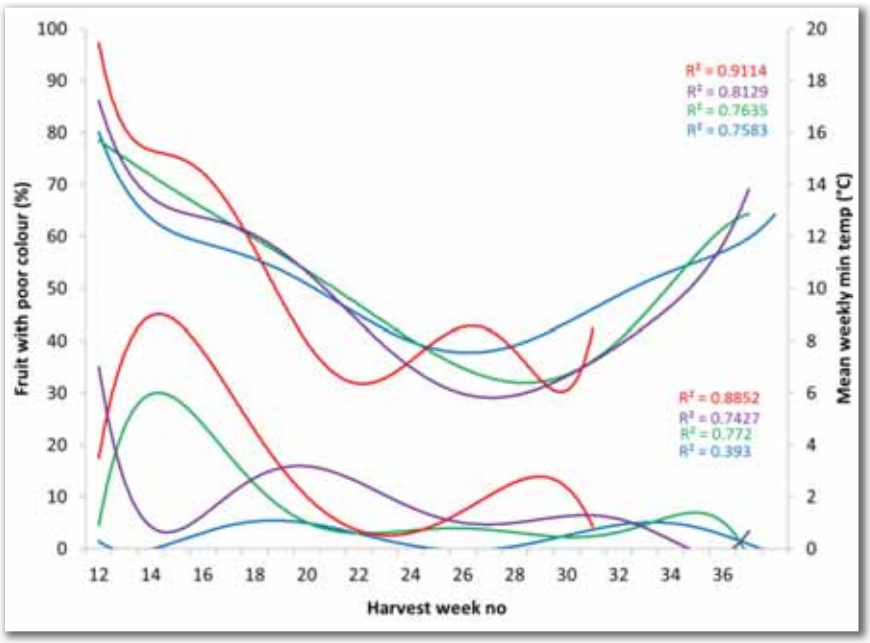

Figure 16. Poor colour in 'Hass' fruit as recorded by the OTO during four recent seasons (bottom set of polynomials on Y1 axis) and the mean weekly temperature in Nelspruit (top set of polynomials on Y2 axis) for the respective periods.