New advances in the development of quality assurance norms for the South African avocado export industry

D Lemmer, T R Malumane, Y Nxundu, J Tandane and F J Kruger

ARC-Institute for Tropical and Subtropical Crops,
Private Bag X11208, Nelspruit 1200, South Africa
E-mail: daniel@arc.agric.za

ABSTRACT

As part of the continuous improvement of South African export avocado quality, the storage potential of avocados from 60 orchards in the most problematic Kiepersol area was determined during the 2003/04 season. The mineral content of the fruit was measured on a monthly basis as from December 2003 to March 2004. Storage trials commenced upon reaching the 82% fruit moisture content level during April and continued on a weekly basis until moisture content levels of approximately the 62% were reached. SmartFresh™ applications were made at the commercial dosage throughout the trial as well as at a higher dosage when fruit moisture content levels dropped below 71%.

In Fuerte and Pinkerton the incidence of grey pulp was found to increase in a familiar fashion as the season progressed. The incidence of the disorder was, however, higher in Fuerte than in Pinkerton. In the absence of SmartFresh™, grey pulp was already present at around 75% fruit moisture in fruit from nitrogen rich orchards, while in nitrogen poorer orchards it started to appear at around the 68% mark.

When SmartFresh™ was applied at the commercially used concentration, the incidence of grey pulp only occurred where fruit moisture content was 66% or less. With the higher SmartFresh™ dosage it was possible to stretch the grey pulp-free period to when the fruit reached 64% moisture.

In Hass, very little to no grey pulp occurred in orchards where the pulp nitrogen was within specification. In a single Hass orchard where the nitrogen was considerably higher than the recommendation at the January cut-off point, the incidence of grey pulp was high at the beginning of the season while it disappeared towards the end of the season. This pattern is completely opposite to the norm. However, we have observed similar trends in the past and it would seem to have been brought about by heavy rains approximately 2 months prior to harvest.

In so far as black cold damage was concerned, Fuerte and Pinkerton displayed classical incidence patterns. In both cultivars, black cold damage was a problem at the beginning of the harvest window and not the end. However, several Hass orchards showed an uncharacteristic pattern in that black cold damage developed towards the end of the harvest window. The lesions did, nevertheless, seem to differ morphologically from the early season lesions. Early season lesions were typically larger and coalesced while late season lesions were smaller and did not readily coalesce. We are presently of the opinion that the late season black cold damage was also brought about by the climatic conditions responsible for the uncharacteristic early season grey pulp observed in the one Hass orchard.

In general, the quality of Edranol fruit was poor, while that of Ryan was excellent. This year's results further appeared to confirm last year's notion that an association exists between the large-lesion, classical, early season, black cold damage symptoms and the iron content of the fruit. However, in the case of the smaller end-of-season lesions, iron would seem to play less of a role while calcium deficiency on the other hand may possibly be a contributing factor.

INTRODUCTION

This study is a continuation of the project started during the mid 1900's that aimed to improve the storage quality of South African avocados. The aim of the initial study was to establish appropriate harvest maturity and pulp nitrogen content norms for the five export cultivars grown in the main production regions.

Over the last two years, a number of important changes have occurred in so far as the marketing of South African avocados is concerned. Increased competition is increasingly forcing the industry to test the currently prescribed maturity cut off points. The need to store the fruit for extended periods has also come to the fore, while phytosanitary endeavours have highlighted the necessity to reduce the intrinsic susceptibility of the fruit to black cold injury.

On the positive side a new tool, SmartFresh™ (1-methyl cyclopropene), has become available to reduce grey pulp.

The first aim of the present study was to establish to what extent the currently prescribed maturity cut-off points can be stretched. Amongst other aspects, this involved relating the current pulp nitrogen norms (Kruger *et al*., 2004) to the grey pulp-reducing potential of SmartFresh™. The second aim was to follow up the observations made during the last season regarding a possible link between low pulp iron content and increased susceptibility to black cold injury.

MATERIALS AND METHODS

Mineral analysis

Fruit samples were taken on a monthly basis from 60 orchards in the Kiepersol area as from December 2003 to March 2004. The samples were collected from seven producers delivering fruit to the Burpak and Koeltehof packinghouses. In terms of cultivars, the survey covered 31 'Hass', 13 'Fuerte', 12 'Ryan' and 4 'Edranol' orchards. Mineral analysis entailed pooling the pulp of 10 fruits and determining the N, K, Fe, Ca and Mg contents of the sample.

Maturity

Storage trials commenced on a weekly basis once the fruit reached the 82% moisture content level and usually continued until the 62% level was reached, depending on the quality of the fruit. Where possible, bigger counts (10-12) as well as smaller counts (16-18) were included in the storage trials. Furthermore, SmartFresh™ treatments were made at the commercially used dosage. Upon fruit moisture content reaching the 70% mark an additional, higher SmartFresh™ dosage was also included.

Two 4 kg boxes, each of the different counts, were stored for 28 days at the maturity related commercial export temperatures used by the industry (Vorster *et al*., 1990). The fruit were hereafter ripened at 180ºC and evaluated upon ripening. The full range of evaluation criteria, including the number of days to ripen and the incidence of disorders, were recorded.

RESULTS AND DISCUSSION

As can be appreciated, a large volume of data was collected during the trial. Through experience, we have learnt that the most useful way of demonstrating a specific trend, is to present the data as case studies. For this purpose, we have selected two 'Hass' case studies and one each of 'Fuerte', 'Pinkerton', 'Ryan' and 'Edranol'.

Current mineral content and maturity recommendations

Before reviewing the particulars of the present case studies, it is appropriate to first refer to our recommendations regarding pulp nitrogen content as proposed by Kruger *et al*. (2004). In the case of Kiepersol Fuerte, it is recommended that the pulp nitrogen content not be higher than 1.7% in December and this must reduce to under 1% by February. It should then ideally remain just below 1% or slowly decrease but not fluctuate.

Unfortunately, the maturity cut-off points are not as simple to formulate. The reason for this is that a range of factors are known to play a role (Kruger *et al*., 2004). For example: during an on-year and a dry season, a smaller count Fuerte fruit that meets the above nitrogen pulp specifications may be left to hang until the 65% fruit moisture content mark is reached, provided that it is exported under CA or SmartFresh™ conditions. The proposed moisture content based maturity cut-off points, however, increase as conditions worsen. The worst case scenario concerns a large fruit produced in an over-fertilised heavy soil at a low altitude during a rainy, off-season and exported under RA conditions. The moisture contenct of such a fruit must preferably be 75% or higher to prevent grey pulp.

In the above study, a negative correlation was also found between the iron content of the fruit and the incidence of black cold injury. Since then we have found indications not only in avocados, but also with mangoes and citrus, that a positive correlation exits between fruit pulp/rind nitrogen and iron contents (Kruger, *et al*., 2005, Kruger & Grovè, 2005).

Fuerte

In preparation of the interpretation of the results, it is necessary to provide some information regarding the Frankfort farm to which the illustrative Fuerte case study refers. Although Frankfort is located in the problematic Kiepersol district, it is not located in the most problematic low lying heavy soils on which bananas were formerly cultivated. It is situated at a higher altitude in a lower potential forestry area. During previous seasons, the pulp nitrogen content of fruit from this farm was found to be higher than the prescribed 1.7% in November/December. It, however, promptly reduced to around 0.6% by February, which is considerably lower than the prescribed 1%.

For the present study, the incidence of grey pulp and black cold injury in orchard F5 was selected. This particular orchard was established on ridges against a north-facing slope. Trees at the very bottom of the orchard, where run-off water accumulates, are greener and have higher leaf nitrogen levels than the rest of the orchard.

For the purpose of this study, samples were taken from the top as well as the very bottom of the orchard. Fruit from the bottom row was found to have a nitrogen content of 1.1% during February, which is slightly higher than the prescribed 1%. Those from the top rows, had a pulp nitrogen content of 0.67%, which is very low for February.

The iron content of the two sets of trees also differed. The pulp of fruit from the top end of the orchard contained 28 ppm iron, while those from the bottom end contained 63 ppm. Nitrogen-starved trees were therefore found to contain lower levels of Fe.

The incidence of grey pulp and black cold damage, as recorded on 13 dates after 28 days storage at the maturity based commercial export temperatures, is shown in Fig. 1a-d. A number of very interesting trends emerge in so far as grey pulp (Fig. 1a & b) is concerned:

- In both small and big fruit the incidence of grey pulp increased in a, by now familiar, fashion as the season progressed.
- As expected, the incidence of grey pulp was higher in fruit from the nitrogen richer bottom end of the orchard compared to the nitrogen poorer top end of the orchard.
- In accordance with previous results (Lemmer *et al*., 2003), larger fruit had a higher incidence of grey pulp than smaller fruit.
- In the absence of SmartFresh™ treatment, grey pulp was already present as from the first trials (Moisture content *circa* 75-76%) conducted with fruit from the nitrogen richer part of the orchard. In fruit from the nitrogen poorer part of the orchard, grey pulp only started to appear at around 67-68% mark.
- When SmartFresh™ was applied at the commercially used concentration, the incidence of grey pulp was totally controlled, up to the 66% mark, in big fruit from the nitrogen rich part of the orchard.
- With the higher SmartFresh™ dosage, it was possible to stretch the grey pulp free period to a fruit moisture content of 64%.

As is the case with grey pulp, Fig. 1c & d also demonstrate some familiar trends in so far as black cold damage is concerned:

- In contrast with grey pulp and in unison with previous results, the incidence of black cold damage was found to be higher at the beginning of the season and it virtually disappeared towards the end.
- Fruit from the nitrogen richer part of the orchard also contained higher concentrations of iron and *vice versa*.
- In contrast with grey pulp, black cold damage was more prevalent in fruit from the part of the orchard that had a lower nitrogen and iron content.
- In contrast with grey pulp, black cold injury was more prevalent in smaller fruit than in larger fruit.

On the whole, the results attained with Fuerte confirmed those of our previous years regarding the maturity cut off points, fruit pulp nitrogen recommendations, effects of CA and SmartFresh™ as well as the negative correlation between the pulp iron content and the incidence of black cold damage.

Pinkerton

In this case study the incidences of grey pulp and black cold damage, as recorded in two Frankfort orchards (P1 & P2), are shown in Fig. 2a-d. The 'end of February' nitrogen content of orchard P1 was higher than the prescribed 1% at 1.12% while that of orchard P2 was lower at 0.81%. In general, the results attained were fairly similar to those recorded for Fuerte, but there were certain differences.

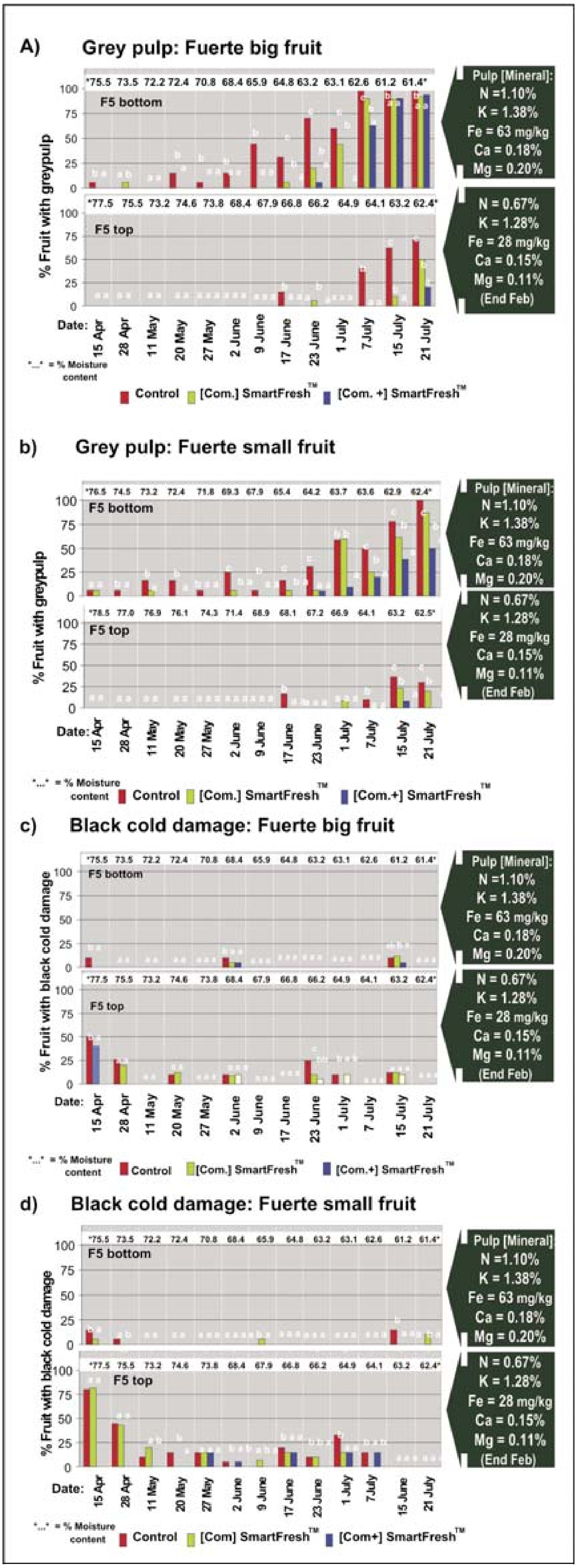

Figure 1. Incidence of grey pulp (a & b) and black cold damage (c & d) in larger, count 10-14 (a & c) and smaller, count 16-20 (b & d) Fuerte fruit from the top and bottom end of orchard F5 at Frankfort. Count size obviously depended on sampling date.

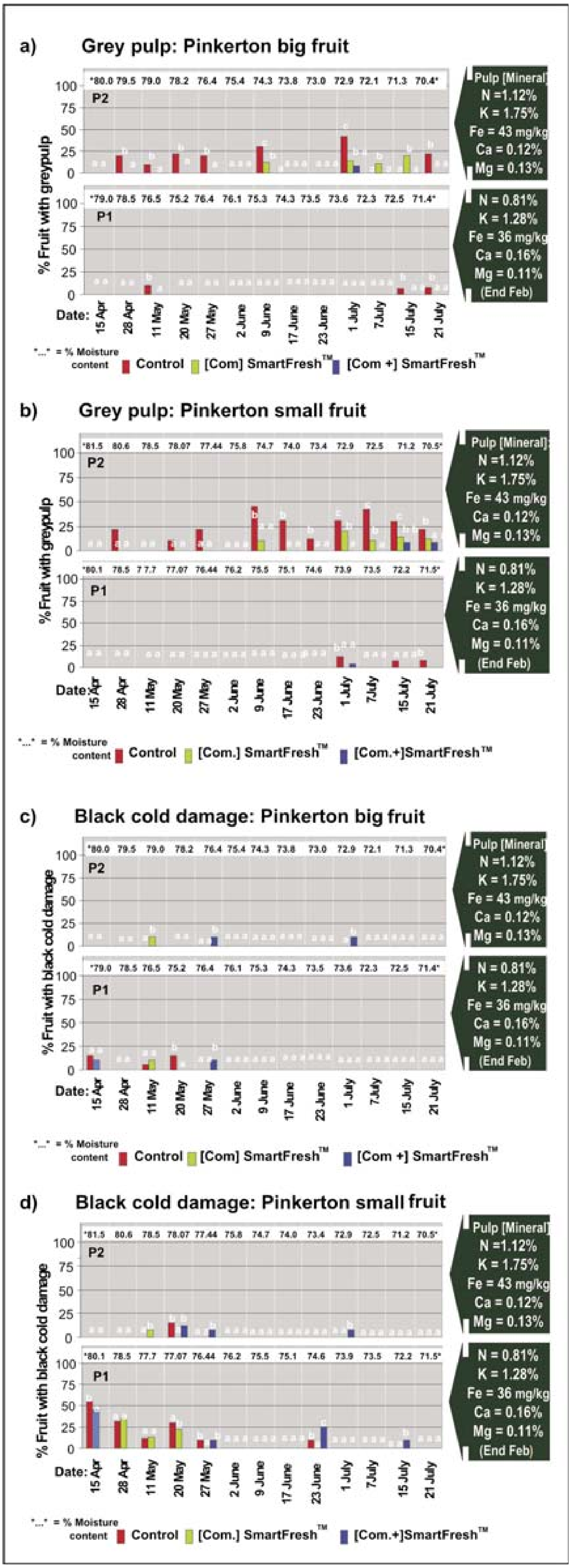

Figure 2. Incidence of grey pulp (a & b) and black cold damage (c & d) in larger, count 10-14 (a & c) and smaller, count 16-20 (b & d) Pinkerton fruit from orchards P1 and P2 at Frankfort.

Grey pulp:
- The mean seasonal incidence of grey pulp was lower in Pinkerton than in Fuerte.
- As was the case with Fuerte, the incidence of grey pulp was higher towards the end of the season.
- As was the case with Fuerte, the incidence of grey pulp was significantly higher in fruit from the orchard that had the higher pulp nitrogen content at the end of February.
- In contrast with Fuerte, where the incidence of grey pulp was considerably higher in bigger fruit, the effect of fruit size was less clear in Pinkerton.
- SmartFresh proved to be equally effective in Pinkerton and Fuerte.

Black cold damage:
- As was the case with Fuerte, black cold damage was higher at the beginning of the season than at the end.
- As was the case with Fuerte, black cold damage was higher in smaller fruit than in bigger fruit.
- As was the case with Fuerte, black cold damage was lower in fruit from the orchard with a higher nitrogen and iron content.

Hass

Only fruit from one of the 31 Hass orchards surveyed showed grey pulp symptoms. The statistics from this orchard (H15) and a comparative orchard (H14) from the same farm (Langspruit) are shown in Fig. 3. The February pulp nitrogen content of orchard H15 was far above the 1% norm, at around 1.48% during February, while that of the second orchard (H14) was within specification at 0.98%. The orchards had similar pulp iron contents (59 vs 55 ppm), but in addition to a high nitrogen content, the fruit from orchard H15 also had a low calcium content (0.03% vs 0.16%). As the size distribution did not allow for the sampling of big and small fruit, as was done with Fuerte and Pinkerton, only medium sized Hass fruit were used.
- The orchard where the pulp nitrogen content was out of specification (H15) had a significantly higher incidence of grey pulp than the orchard where the nitrogen was within specification (H14).
- In orchard H15, the incidence of grey pulp was high at the beginning of the season but it went away as the fruit matured. This pattern is completely opposite to what was expected.
- The incidence of black cold damage was high in orchard H15 and virtually absent in orchard H14.
- Black cold damage was absent during the beginning of the season but became a problem towards the end. This observation was also opposite to what was expected.

For the subsequent example, two orchards (L21 and L25) from the same farm (Koeltehof) were selected. Orchard L25 was chosen because it had the highest incidence of black cold damage of all 31 Hass orchards surveyed, while orchard L21 is a typical Koeltehof orchard. The nitrogen content of orchard L21 was within specification (0.87%) while that of orchard L25 at 1,25% was not (at 1.25% it was nonetheless considerably lower than the 1.48% of orchard H15 in the previous example). The iron content of fruit from both orchards was high but the calcium content of orchard L21 (0.15%) was four times that of orchard L25 (0.04%).
- Very little grey pulp occurred in the two orchards.

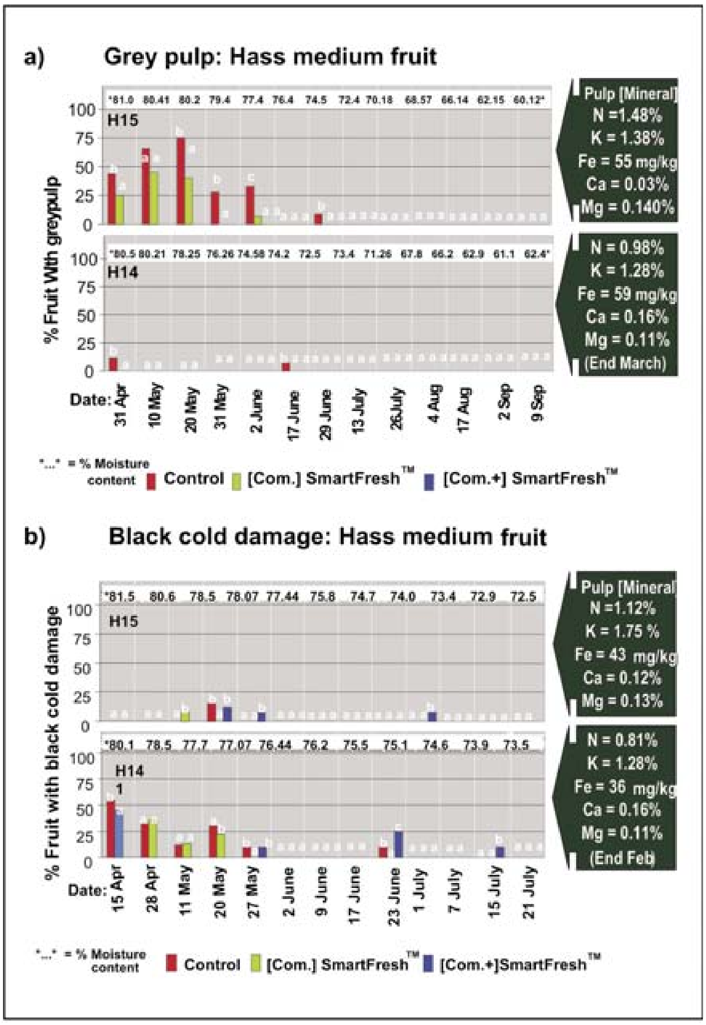

Figure 3. Incidence of grey pulp (a) and black cold damage (b) in count 14-18 Hass fruit from orchards H14 and H15 at Langspruit.

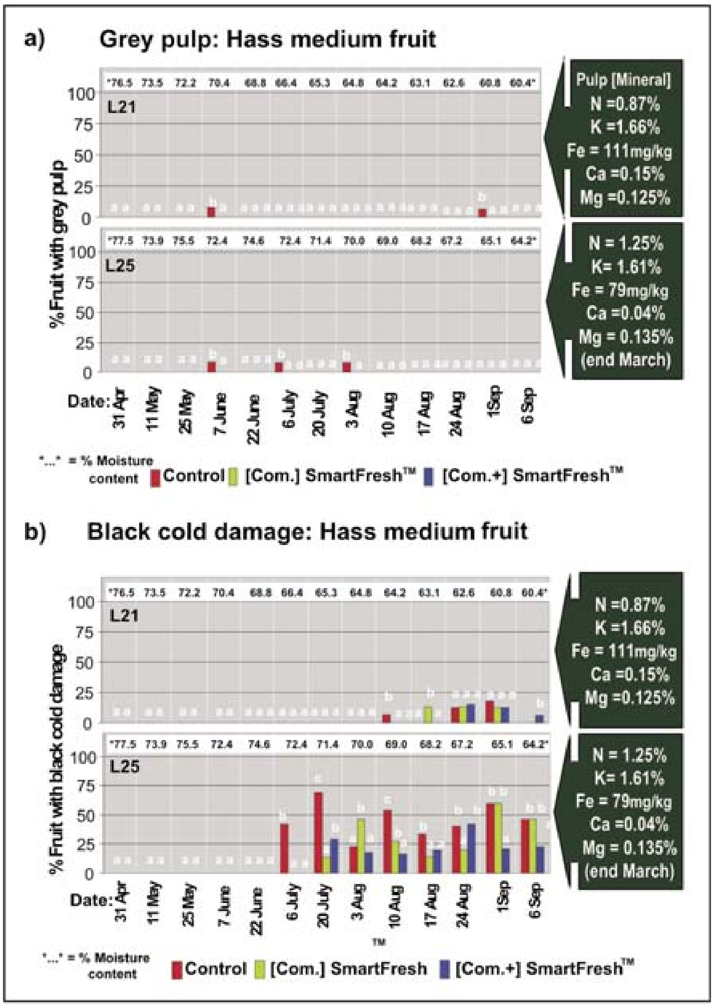

Figure 4. Incidence of grey pulp (a) and black cold damage (b) in count 14-18 Hass fruit from orchards L21 and L25 at Koeltehof.

• The incidence of black cold damage was higher in the orchard with the lower Ca content (L25) compared to the orchard with the higher Ca concentration (L21).

• The incidence of black cold damage was highest towards the end of the season. This was the exact opposite to what was expected.

The results pertaining to grey pulp concur with present recommendations regarding the association between grey pulp and excessive nitrogen fertilisation. However, the reverse incidence pattern of both grey pulp and black cold injury needs to be addressed. This will be discussed in later sections dealing with, firstly, the influence of climate on physiological disorders and secondly, the relationship between Fe and Ca on the one hand and black cold damage on the other.

Edranol

For the Edranol example, two orchards (L28 & L29) on the farm Harmony were selected as illustrative examples. Orchard L28 had a pulp nitrogen content of 1.38% during January while that of orchard L29 was 1.05%. Orchard L28 was also more mature than orchard L29 by approximately 2 moisture content percentage points during the harvest period.

• The later maturing orchard (L29) showed the less common early season high incidence grey pulp pattern recorded for Hass in the present study. However, unlike Hass, the grey pulp persisted, albeit at a lower incidence during the second half of the season.

• In the earlier maturing, high nitrogen orchard L28, the above pattern as well as the classical late season maturity related grey pulp peak, as recorded for Fuerte and Pinkerton in the present study, occurred.

• In a similar fashion to Hass, black cold damage occurred in orchard L29 towards the end of the study.

The differences between the two orchards regarding the time of season that the grey pulp symptoms appeared, is important in terms of later discussions regarding the effect of rainfall on the emergence of physiological disorders.

Ryan

The lower availability of Ryan orchards did not allow for comparison of orchards on the same farm. In the present example, orchard L26 at Koeltehof was compared with orchard R1 at Frankfort. The February pulp nitrogen contents of the orchards were similar (0.91% and 0.89%) but the iron content of the orchards differed considerably. The iron content of orchard L26 was 129 ppm while that of orchard R1 was 36 ppm during February. Orchard L26 was further characterised by having big fruit while the fruit from orchard R1 were smaller.

• Grey pulp was virtually non existent in both orchards.

• Only the smaller fruit from the orchard with the lower pulp iron content (R1) showed black cold injury symptoms.

The trends recorded for Ryan fit in with our present perceptions regarding the pulp nitrogen and iron levels.

The possible role of rainfall on the development of uncharacteristic early season grey pulp

In the present study, it was found that Fuerte and Pinkerton display classical grey pulp incidence patterns. In both cultivars, grey

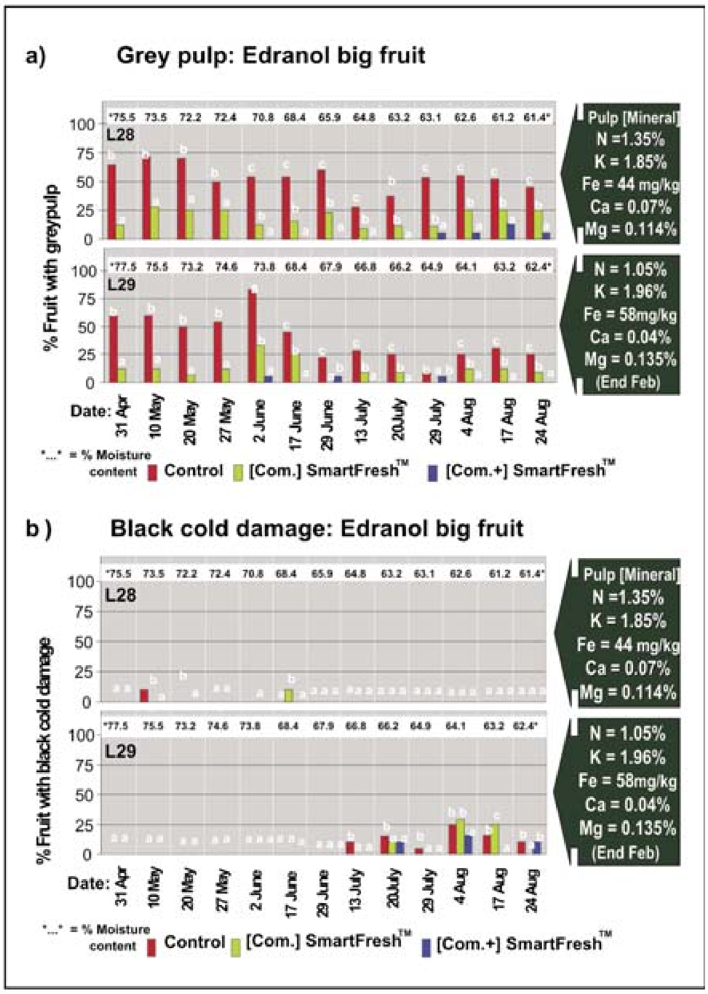

Figure 5. Incidence of grey pulp (a) and black cold damage (b) in count 14-18 Edranol fruit from orchards L28 and L29 at Harmony.

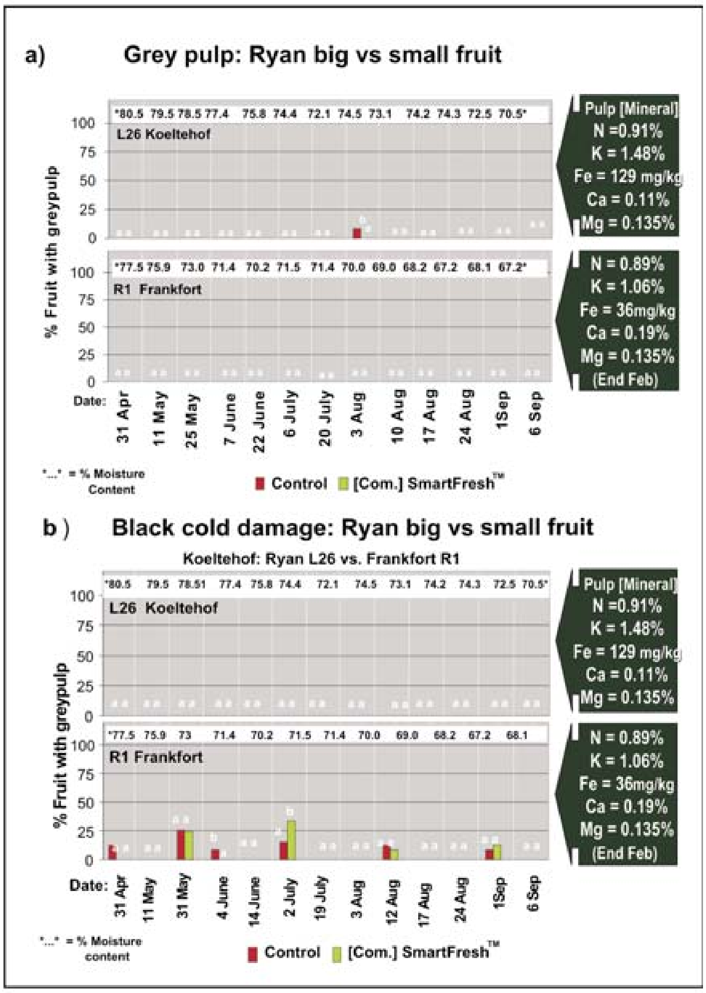

Figure 6. Incidence of grey pulp (a) and black cold damage (b) in count 10-14 Ryan fruit from orchard L26 at Koeltehof and in counts 16-20 fruit from orchard R1 at Frankfort.

pulp became a problem towards the end of the season. However, as mentioned, one of the 31 Hass orchards surveyed developed grey pulp at the beginning of the harvest window. Although this particular orchard was found to have the highest fruit pulp nitrogen levels of the 31 Hass orchards surveyed, it does not explain why the grey pulp occurred at the beginning of the season and then disappeared.

During the 1996 season, a similar trend was observed by Kruger & Claassens (1997). Grey pulp developed during the early part of the season in retention samples kept at Westfalia Estates. In an attempt to explain this, Kruger & Claassens (1997) compared the rainfall pattern of the preceding period with the grey pulp and pulp spot incidence patterns of respectively Hass and Fuerte and found the fruit to be particularly susceptible to grey pulp at a specific point in time after heavy rains. In the case of pulp spot in Fuerte, they found this period to be approximately two and half months, while in the case of grey pulp in Hass this period was about two months. When calculating the period between the end of season rainfall recordings and the highest incidences of grey pulp in the nitrogen rich Langspruit H15 Hass orchard, it would appear that it may also be between 2 and 3 months.

The above association between rain and early grey pulp may possibly explain why it was found in the current study that the later maturing (L29) Edranol orchard also developed grey pulp during the early season, while the earlier maturing nitrogen rich orchard L28 exhibited both the early and late peaks.

A note on the relationship between Fe, Ca and black cold injury

In the present study, it was found that Fuerte and Pinkerton display classical black cold damage incidence patterns. In both cultivars, black cold damage was a problem at the beginning of the harvest window and not the end. However, in the case of Hass, uncharacteristic black cold damage symptoms developed towards the end of the harvest window. This trend was also reflected by industry statistics (Nelson, 2004).

Early and late season lesions differed morphologically. Early season lesions were typical of what is perceived by the industry as black cold damage. The lesions were large and coalesced. On the other hand, the late season lesions were smaller and were reminiscent of a senescing rind. We are therefore presently of the opinion that the late season black cold damage was atypical. Although we do not have evidence to support it, we are currently of the opinion that the uncharacteristic late season rind senescence symptoms may have been brought about by the same factors that caused the uncharacteristic early season grey pulp symptoms observed in the single Hass orchard. However, in this case it would seem that low fruit calcium levels may have contributed to rind senescence towards the end of the season.

LITERATURE CITED

KRUGER, F.J. & CLAASSENS, V.E. 1997. What went wrong with export avocado physiology during the 1996 season? *South African Avocado Growers' Association Yearbook* 20: 88-92.

KRUGER, F.J. & GROVÉ, T. 2005. Further observations on the use of the immobile element composition of mango fruit as an indicator of susceptibility to lenticel damage. *South African Mango Growers' Association Yearbook* 25: In preparation.

KRUGER, F.J., PENTER, M., MASHEVE, R. & COMBRINK, N.K. 2005. The use of fruit mineral content as a tool to investigate the epidemiology of citrus rind disorders. *South African Fruit Journal*, 4(2): 54-59.

KRUGER, F.J., SNIJDER, B., MATHUMBU, J.M., LEMMER, D. & MALUMANE, R. 2004. Establishing appropriate maturity and fruit mineral content norms for the main avocado export cultivars. *South African Avocado Growers' Association Yearbook* 27: 10-16.

LEMMER, D., BEZUIDENHOUT, J., SEKHUNE, S., RAMOKONE, P., LETSOALO, L., MALUMANE, T.R., CHIBI, P., NXUNDU, Y., HOBSON, M. & KRUGER, F.J. 2003. Semi-commercial evaluation of Smartfresh™ with South African export avocados in static containers at the Westfalia packhouse during 2002. *South African Avocado Growers' Association Yearbook* 26: 55-61.

NELSON, R. 2004. Avocado arrival quality report for 2004. Unpublished report.

VORSTER, L.L., TOERIEN, J.C. & BEZUIDENHOUT, J.J. 1990. Temperature management of avocados – an integrated approach. *South African Avocado Growers' Association Yearbook* 13: 43-46.