Research towards reducing the incidence of lenticel damage of South African 'Hass' export avocado fruit

D Lemmer and JF Fourie

ExperiCo, Agri-Research Solutions
Lelie Street, Stellenbosch 7600, SOUTH AFRICA

E-mail: danie@experico.co.za / johan@experico.co.za

ABSTRACT

The avocado industry requires solutions to reduce lenticel damage. An industry protocol for the reduction of lenticel damage is in place, however, it needs to be established whether these guidelines are adhered to. A project was initiated to visit producers before and during harvest, to establish practices followed. The project further included a study to establish the relationship between the incidence of lenticel damage and nutrient composition of skin/pulp in avocado. A noteworthy finding of the 2019 study was that most producers do not adhere to the protocol of: "Avoid picking from orchards with soils at field capacity, as this could increase susceptibility to lenticel damage". Harvesting fruit at "drier" soil moisture (probe reading +4 mm) provided fruit with less lenticel damage, compared to fruit harvested from the same orchard at a soil moisture content of -5.5 mm. In another instance, a producer who was forced to stop irrigating ± 1 month prior to harvest due to water shortage, obtained 70% sound fruit, 25% Grade 1 and 5% Grade 2 damage, with no fruit of Grade 3 damage. The incidence of lenticel damage was in most instances directly associated with handling during picking, transport and packing, increasing as additional practices were included during the handling chain. Grade 3 extensive damage, according to the PPECB lenticel grading protocol, only occurred on fruit sampled from the pack-line. Handling fruit with care during harvesting, transport and packing is essential to ensure that less damage develops during storage. Questions arising from this study are to what extent irrigation should be reduced close to harvest and whether the industry is not impulsively over-irrigating. A need seems to exist to redefine the present protocol for suitable soil moisture as to reduce lenticel damage, however, soil type should be considered along with irrigation cycles. The results obtained warrant further research. In the nutrition trial, three foliar applications of various calcium nitrate concentrations were applied in a low nitrogen orchard, in an attempt to increase nitrogen and calcium content in the skin of 'Hass', as a possible means to minimise lenticel damage. Late applications of $Ca(NO_3)_2$ increased N levels but not Ca, and should rather be avoided, since lenticel damage was increased rather than reduced, especially when avocados are handled without care. Incidence of lenticel damage, as well as Anthracnose, was higher on avocados subjected to "jostling" (manhandled by tumbling) prior to packing, escalating as pre-harvest $Ca(NO_3)_2$ dose rate was increased. None of the factors indicated to be associated with lenticel damage can or should be seen as the sole cause, but rather that a number of conditions contribute towards the defect, which needs to be addressed.

INTRODUCTION

Lenticel damage is a disorder of avocados, manifesting as brown or black spots of 1-5 mm diameters on the fruit skin. Lenticel damage is more severe when fruit are harvested wet (Duvenhage, 1993), however, the aetiology of lenticel damage is not known. This disorder occurs when the fruit skin is damaged in the region of the lenticels. When undamaged, lenticels are visible as light speckles on the fruit surface. Lenticels become very sensitive and are highly susceptible to handling damage when the fruit skin is fully turgid, becoming noticeable once placed in cold storage (Donkin, 2005). In the past, lenticel damage was mainly perceived to be a problem of 'Fuerte', with unsightly brown or black speckles occurring on fruit that remain green when ripe. 'Hass' was seen to be of a lesser problem, since lenticel damage is hardly visible once the fruit has fully coloured and ripened. However, more 'Hass' with lenticel damage occurs on the market, with buyers selecting "clean fruit", without visible lenticel damage. For suppliers the equation is clear-cut: "Clean fruit you win, lenticel damage, you lose". To assist growers and packhouse managers to reduce/prevent lenticel damage,

Derek Donkin (2005) drafted a detailed document of protocols to be applied during picking and at the pack-house.

Information regarding skin/pulp mineral content and the possible influence on the incidence of lenticel damage is lacking for avocados, however, information is available for other subtropical crops. Kruger *et al*. (2003a; 2003c; and 2005) and Kruger and Fraser (2004) highlighted the benefits of using fruit nitrogen content as a supplementary tool to predict and manage occurrence of rind disorders, and increase storage potential of subtropical fruit crops. Preliminary results (Kruger *et al*., 2003a; 2003c) showed that the incidence of mango lenticel damage has some bearing on fruit moisture and nutrients, particularly nitrogen content. Subsequent results confirmed a relationship between the mineral composition of the fruit and the incidence of lenticel damage (Kruger and Fraser, 2004). Rind and pulp of less susceptible fruit was found to contain significantly lower levels of immobile elements such as calcium, manganese, iron and copper. A similar study was conducted on citrus fruit (Kruger and Grove, 2005). It was reported that over-fertilising with nitrogen contributes to rind pitting in grapefruit and oranges. Rind pitting was not only experimentally induced by over fertilising trees, but was also eliminated when the leaf nitrogen content of problematic commercial grapefruit orchards was reduced. A similar survey in 'Midknight' oranges further maintained that fertilising with excess nitrogen is a major cause of rind pitting (Lemmer *et al*., 2005). Due to the role of calcium in cell wall structure and membrane function, calcium has been implicated in the physiological disorders of many fruit (Poovaiah *et al.*, 1988).

The possible influence on lenticel damage in avocados with regard to differences in fruit skin Ca content has not been investigated. It is well known that nitrogen can negatively affect the absorption of other immobile nutrients such as Ca and micro nutrients. Low nitrogen leads to low Fe absorption, which in its turn relates to Black-cold-damage in 'Fuerte' (Lemmer *et al*., 2004). Physical damage due to rough handling during picking increases lenticel damage in mangoes and is further exacerbated by picking after rain. Physiological disorders due to a relationship between the mineral composition of fruit may also influence the incidence of lenticel damage (Kruger and Fraser, 2004). Therefore, research towards attaining important knowledge regarding the relationship between avocado skin/pulp mineral composition and lenticel damage is needed.

Objectives

The milestones for the three-year project co-funded by the PHI-programme include:

(i) To conduct a database survey/study, regarding the occurrence of lenticel damage of the past seasons, as recorded by Juan Winter as a starting point, to identify producers/orchards with and without lenticel damage, and to monitor compliance to the handling protocols of Donkin (2005).

(ii) To determine the influence of handling 'Hass' fruit on an orchard level to the occurrence of lenticel damage after storage.

(iii) To identify leaf, fruit and pulp nutritional differences in orchards with and without lenticel damage that could contribute to differences in lenticel incidence for 'Hass'.

(iv) To investigate if a foliar application of calcium nitrate in a low nitrogen orchard, in an attempt to increase nitrogen and calcium content of 'Hass' fruit skin, will minimise lenticel damage.

MATERIALS AND METHODS

TRIAL 1 (2019)

Objective 1 – Conduct a database study by visiting producers during the harvesting of 'Hass'

A database study was conducted by Juan Winter on the occurrence of lenticel damage of the past seasons for 'Hass' with the intention of identifying 8 producers, 3 producers/orchards with and 5 without the probability of developing lenticel damage on fruit. Producers were visited before and during harvest to establish differences in harvest practices.

Information gathering and fruit sample collection for evaluation and analyses include:

- Monitoring of weather conditions during harvest = **Stipulation 1**:
  - Establish presence of dew during harvest
  - Verify occurrence of rain prior to and during harvest
- Monitoring of harvest procedures during picking = **Stipulation 2**
  - Identify possible improvements to be introduced for reducing lenticel damage
- Soil-moisture readings = **Stipulation 3**
  - Confirm adherence to protocol for harvest
- Fruit quality evaluations
  - Conduct evaluations on fruit samples after storage for 25 days (simulating export conditions), taken at different handling stages, with a focus on lenticel damage.

TRIAL 2 (2019)

Application of calcium nitrate in a low nitrogen orchard

A low nitrogen 'Hass' orchard was identified in the Haenertsburg area and the leaf nutrient data was supplied by the producer.

Trial detail:

- Application of calcium nitrate foliar treatment at 70% moisture content (MC), 30 days before being harvested at 65% MC. Three sprays were applied at 10-day intervals. Calcium nitrate was applied at 0, 0.2, 0.35 and 0.5%, with 5 trees per replication.
- Harvest fruit at 65% MC (12 boxes of count 16; 15 fruit per box; 6 replicates). Fruit were sampled during the late season at ± 65% MC to verify differences across calcium nitrate treatments in lenticel damage development.

- Subject fruit harvested with care to physical rolling in a 10 L bucket according to the "Jostle method" developed in New Zealand to assess sensitivity to lenticel damage.
- Stored at 5°C for 25 days to simulate export conditions.
- Conduct fruit quality evaluations on samples after storage and ripening at room temperature.
- Assess moisture content and nutrient composition in fruit skin and pulp (nitrogen and calcium) at harvest on 10 randomly selected fruit.
- Conduct moisture content and mineral nutrient analyses (pulp and skin) using the ARC Soil Science Laboratory at Nelspruit (10 randomly selected fruit).

Statistical analyses

Statistical analyses were conducted on 5 (Trial 1) or 6 (Trial 2) replicates per treatment. The data were subjected to two-way analyses of variance (ANOVA), using Statistica (statistical software).

RESULTS AND DISCUSSION

TRIAL 1

Objective 1 – Orchard visits during harvesting of 'Hass' and compliance to industry protocols

In collaboration with Juan Winter, using the Loss Factor Database of the past 4 seasons, 8 producers, 5 with a high incidence of lenticel damage and 3 with a low incidence, were identified (Table 1). Orchards of these producers were visited from 9 May to 9 September 2019, to enable assessments prior to and during harvest, to identify differences in handling practices and to procure fruit samples for later evaluation of lenticel damage. It was decided to use the current SAAGA industry protocol (2005) for reduction of lenticel damage as a measure to verify if producers adhere to the protocol, and not to intervene or correct them. Initially, an attempt was made to target orchards with different soil moisture probe readings.

However, after visiting the 6 producers as originally planned, it was evident that none were applying the protocol of picking fruit only when a specific soil water content is reached. Hence additional orchards were selected, to increase the number of orchards sampled, and to add additional observational criteria to assist in differentiating between orchards and not between producers, to rather relate activities and practices followed to the incidence of lenticel damage. Subsequently, for the first 6 producers (A to F), one orchard was selected for study purposes, while 3 orchards were selected for producer G (G1, G2 and G3) and 3 orchards for producer H (H1, H2a and H2b), therefore at harvest evaluations were based on the findings of 12 orchards in total.

Findings at orchard level were compared to the SAAGA Protocol (2005), which is aimed at reducing lenticel damage during harvest, based on the following stipulations for harvesting:

Stipulation 1: Avoid picking of wet fruit

Wet fruit is more turgid, making the skin extremely sensitive to lenticel damage. If fruit are wet as result of early morning dew, it is necessary to wait until the fruit has dried off before commencing with picking. As soon as the dew has evaporated, the fruit will lose water through its skin and become less turgid and therefore less sensitive to lenticel damage.

Findings

Dew

- No dew was present on the fruit, despite many producers starting to harvest at ± 07:00.
- Producer G started to pick fruit only from 10:00 in one of the orchards, since this orchard is situated on a ridge, with no direct morning sun.

Suggestion / comment

Producers with orchards at high altitudes, particularly when shaded, should avoid picking early morning, especially when ambient temperatures tend to decline from late May, since wetting from dew may occur, and the fruit skin takes longer to lose moisture taken up during dew conditions.

Rain during harvest

- No rain occurred during the orchard visits. However, rain occurred during the period prior to harvest.
- Producers indicated that if it had rained the day prior to, or on the day of harvest, they would delay picking until the fruit were dry.

Table 1: 'Hass' avocado fruit producers with orchards identified with high and low incidence of lenticel damage the past 4 years

Number	Producer code*	Probability of lenticel damage occurring	Pack-house
1	PA	High	Afrupro
2	PC	High	Afrupro
3	PD	High	Westfalia Packers Politsi
4	PE	High	Afrupro
5	PF	High	Afrupro
6	PB	Low	Afrupro
7	PG	Low	Westfalia Packers Tzaneen
8	PH	Low	Westfalia Packers Politsi

* As requested by Juan Winter the identity of the producers will not be used in the report

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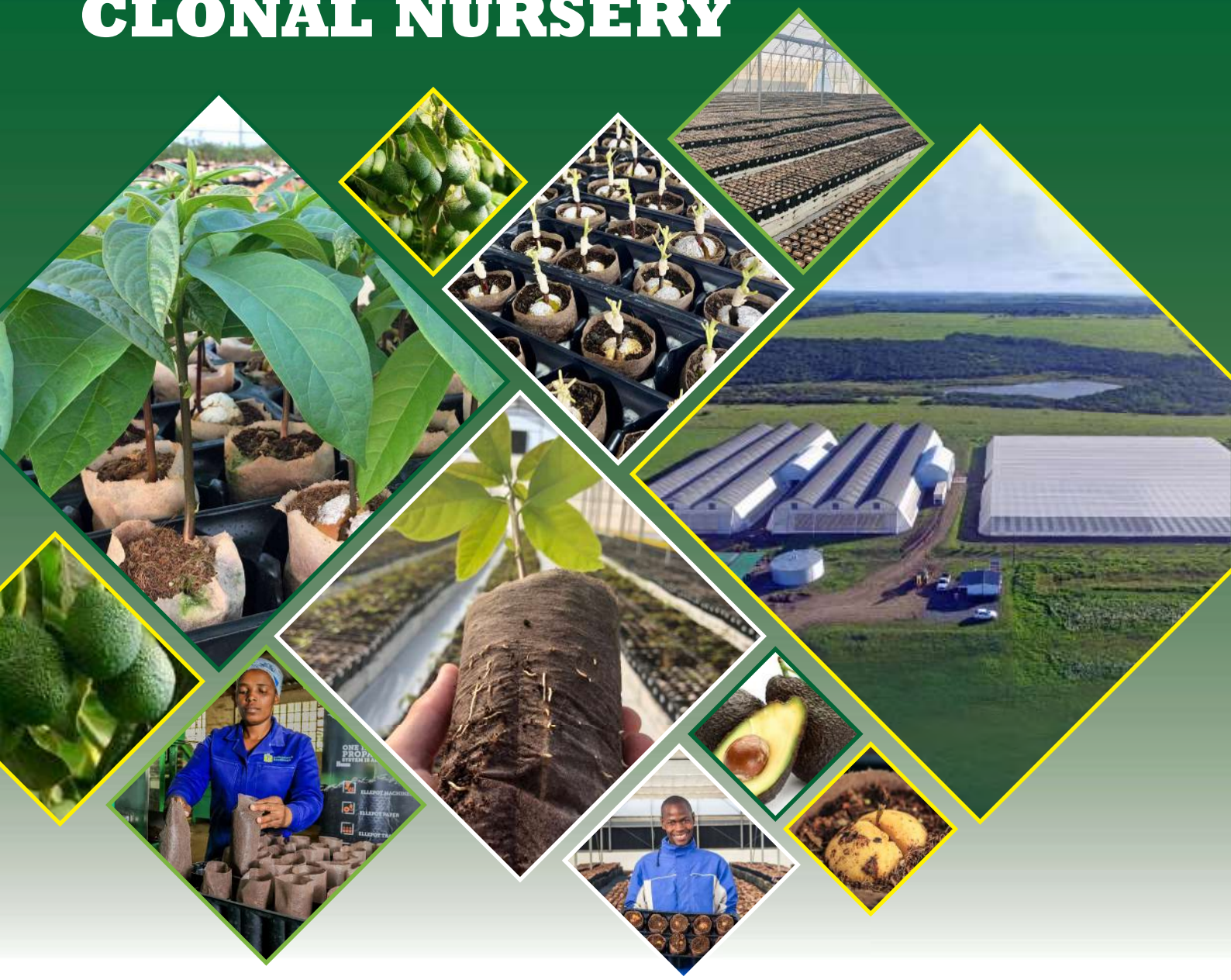

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Suggestion / comment
The time-lapse before harvesting may commence for fruit picked following irrigation and after light or heavy rain, needs to be studied, since an increase in sensitivity for lenticel damage has been indicated – a trial will be considered in the 2020 season.

Stipulation 2: Handling fruit with care during harvest
Even though an avocado is hard when picked, its skin is easily damaged. Rough handling and superficial injuries from long, hardy stems contribute to lenticel damage. Damage as a result of rough handling is seldom immediately visible, but rather expressed during cold storage.

- Lenticel damage already became apparent 24 hours after fruit were placed under cold storage. Where fruit were packed a day later, usually when arriving late in the afternoon at the pack-house, lenticel damage as a result of picking and transport to the pack-house became visible the following day, at time of packing.
- Producer E delivered fruit to the pack-house one day after harvest. Lenticel damage initiated during harvest was already visible upon arrival at the pack-house.
- Producer B made an attempt to reduce injuries from long stems. Fruit with slightly longer pedicels were picked and placed in shoulder bags. When the shoulder bag was full, each picker returned to crates set up in the shade. The shoulder bags were softly laid down on a tarpaulin next to the crates, whereafter 3 fruit at-a-time were removed from the picking bag and the pedicel shortened to the export length of 2.5 mm. The pedicels were then dipped in TBZ solution (early season fruit are dipped in a fungicide solution to reduce stem-end rot) after which the fruit were placed softly into crates (Fig. 1a & b).
- Producer A cut the pedicels to the required length while picking, and then decanted the fruit directly out the bag into crates (Fig. 1c & d). Other pickers of the same producer harvested fruit with longer pedicels and cut it, 3 at-a-time to the required export specification length at the crates.
- Producer C (Fig. 1e & f) picked fruit with longer pedicels and then shortened the pedicels, 2 fruit at-a-time before placing the fruit into crates.
- Producer H harvested fruit with longer pedicels into shoulder picking bags. Full bags were decanted directly into empty crates, by a dropping action (Fig. 2i to k). The pedicels were then cut short to export requirement, 2 to 3 fruit at-a-time, placed back into bags and subsequently taken to bins where they were weighed and emptied.
- Producers E and F harvested fruit into bins (Fig. 2i to k), however, picking teams reduced handling by shortening the pedicels directly at the tree, before placing into shoulder picking bags. At the bins, the shoulder bags were emptied by pickers of producer F by gentle placement in the bin on it's side and by lifting the closed rear flap slowly and hence rolling the fruit carefully out of the bags (Fig. 2e & f).
- Producer G followed a similar procedure, however, pickers did not handle fruit carefully, dropping the fruit from a distance from the shoulder bag directly into the bin without placing the bag on it's side and gently emptying it (Fig. 2g).

Figure 1: Picking procedures of producer A (picture d, e & f), B (picture a & b) and C (picture c & d)

Figure 2: Picking procedures of producer E (picture a - c), F (picture d - h) and producer H (picture i - k)

Suggestions / comments

Handling of fruit with care during harvest is paramount to increase the amount of sound fruit reaching the pack-house and ultimately the client. Handling fruit with care during harvest implies diligent picking, whether by hand with clippers or rod clippers (in-case of bigger trees). Focussed training and consistent supervision is the only way to ensure that fruit is handled with care and that pickers adhere to protocols. Handling time should be minimised where and whenever possible. Fruit should be placed gently into the shoulder picking bags. Picking bags should be emptied with utmost care into bins. Pedicels should be cut short preferably before placement into picking bags.

Stipulation 3: Avoid picking fruit from orchards with soils at field capacity

The SAAGA protocol recommends: "Avoid picking from orchards with soils at field capacity (tensiometer reading of 10-20 kPa), as this will increase susceptibility to lenticel damage". Fruit skin cells will be more turgid and such avocados are not suitable for harvest if soils are at field capacity, or wet due to rain, or wet when harvested directly after irrigation. In general, one of the most important industry protocols as far as control of lenticel damage is concerned, was not adhered to. When the producers were asked if they ensure that the soil is dry enough to harvest, responses were as follows:

"No, I irrigate when necessary";
"I allow drying for 1 to 2 days before harvesting";
"I don't irrigate while harvesting";
"I don't dry out soil before harvesting".

The SAAGA protocol states to avoid picking at field capacity (0-10 kPa). This preferable specification needs to be clarified / reviewed.

Data downloaded from the moisture probes provides readings in mm where 0 mm equates to soil moisture at field capacity.

- Producers either use tensiometers (kPa) or probes (mm) to measure soil moisture to plan and manage their irrigation cycles.
- Most farms visited use moisture probes, to avoid picking from orchards with soils at field capacity, however, dry land producers did not have tensiometers or probes.
- One producer that was not included in the study, only harvested if a tensiometer reading of 20 kPa (500 mm deep, top soil containing most roots) is reached and scheduled harvesting of orchards accordingly.
- Harvesting at a specific soil moisture or delayed harvesting after rain or irrigation, are not the only criteria and procedures that will reduce lenticel damage.
- The findings of adherence or applying the stipulation to avoid harvesting at field capacity at orchard level by the 8 producers are summarised in Table 2.

Information pertaining to the use of tensiometers (internet source)

10-20 kPa (10-20 centibars; cbar)

Readings in the range of 10-20 cbar indicate that there is ample moisture and also air in the soil for healthy plant growth in all types of soil. This range is often referred to as the "field capacity", meaning that the soil has reached its "capacity" and cannot hold any more water for future plant growth. When soil is at "field capacity", any additional water that is added drains out of the root zone within a day or two.

If irrigation has been in process, it should be stopped when a gauge drops to this level, since any further additional water will be quickly drained from the root zone and wasted, carrying with it valuable fertiliser.

- Heavy clay soils: No irrigation required at this time.
- Medium textured soils: No irrigation required at this time.
- Sandy soils: No irrigation is usually required. These soils, however, have a very limited water storage

Table 2: Harvesting practices followed at 12 orchards according to soil moisture parameters or harvesting schedules according to days allowed after rain

Orchard number	Producer code	Probes used	Probe reading (if used)	Number of days allowed after last rain (days)	Other comments
1	A	(-)		9d	Irrigation stopped 1 m prior to picking due to high rainfall (102 mm) during this month
2	B	(+)	-10 mm		
3	C	(-)		30d	Dry land orchard
4	D	(+)	+1 mm	0d	Irrigation taps accidently opened 1 d prior to picking
5	E	(-)		7d	Irrigation stopped 1 m prior to picking
6	F	(-)		7d	Irrigation stopped 1 m prior to picking due to shortage of water on the farm
7	G1	(+)	+10 mm		
8	G2	(+)	+17 mm		
9	G3	(+)	+16 mm		
10	H1	(+)	+2 mm		
11	H2a	(+)	+4 mm		
12	H2b	(+)	-6 mm		

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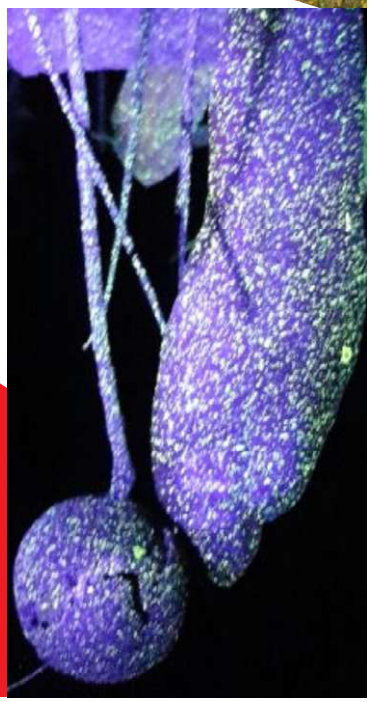

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capacity and therefore soil suction values increase very rapidly as moisture is removed by the plant after soil suction values reach 15-20 cbar.

20-40 kPa (20-40 cbar)
Moisture is available and aeration is good for plant growth.

- Heavy clay soils: No irrigation required.
- Medium textured soils: No irrigation required.
- Sandy soils: Irrigation started for coarser sandy soils in the 20-30 cbar range. For finer sandy soils in the 30-40 cbar range.

40-60 kPa (40-60 cbar)
Moisture is available and aeration is good for plant growth in finer textured soils.

- Heavy clay soils: No irrigation required.
- Medium textured soils: Irrigation started in this range. The finer the texture, the higher the reading before start of irrigation.
- Sandy soils: Too dry. Hot windy conditions can force soil suction to high readings quickly and damage plants.

60-80 kPa (60-80 cbar)
Readily available moisture is scarce, except in heavy clay soils.

- Heavy clay soils: Start of irrigation desirable as soil suction values reach 70-80 cbar.
- Medium textured soils: Too dry. Hot, windy conditions can quickly force soil suction to high reading values and can damage plants.
- Sandy soils: Too dry. Damage to plants may occur.

Objective 2 – Influence of handling 'Hass' fruit at orchard level in the development of lenticel damage after storage

Compare the level of lenticel damage as influenced by the handling chain, by sampling fruit at different points related to activities completed in the handling chain

- Sample 5 replicate boxes of fruit (count 16) at different sampling points as indicated below:
  - In the orchard, after personalised harvest and packing (After box pick)
  - In the orchard, after harvest by pickers, and personalised packing (After farm pick)
  - Personalised pack upon arrival at the pack-house (Upon arrival at the pack-house)
  - From the pack-line, after packing at the pack-house (From pack-line).

Two-way ANOVA of 12 orchards and 4 sampling points (Table 3)
Two-way analyses of variance (ANOVA) was applied by subjecting the data to Statistica (statistical software) and using the LSD test (α = 0.05) to compare treatment means, for Factor A (12 orchards) and Factor B (4 sampling points).

A significant interaction occurred between Factor A (orchard) and Factor B (sampling points).

Table 3: The incidence of lenticel damage on fruit of 12 'Hass' orchards, sampled at 4 points; (a) after personalised box pick and pack, (b) in the orchard from bins after farm picked, (c) upon arrival at the pack-house, and (d) from the pack-line, representing Two-way ANOVA for 12 orchards

QUALITY PARAMETER – INCIDENCE OF LENTICEL DAMAGE (%)											
Factor A (Orchard) x Factor B (Sampling points)						Factor A (Orchard)			Factor B (Sampling points)			
Orchard		(a) Picked into Boxes directly	(b) Farm Pickers	(c) Upon arrival at Pack-house	(d) Packed on Pack-line				(a) Picked into Boxes directly	(b) Farm Pickers	(c) Upon arrival at Pack-house	(d) packed on Pack-line
1.	PF	32.5a	30.0a	32.5a	30.0a	1.	PF	31.2	52.0	60.0	67.7	74.7
2.	PG1	47.5b	53.8defg	61.3ijklm	66.3mnop	2.	PG1	57.2				
3.	PH2a	47.5b	51.3bcdef	65.0lmnop	67.5nop	3.	PH2a	57.8				
4.	PG3	47.8bc	53.3cdefg	57.8ghij	67.8nop	4.	PG3	56.7				
5.	PA	47.5b	56.3fghi	60.0hijkl	68.8op	5.	PA	58.1				
6.	PH1	50.0bcde	55.0efgh	62.5jklmn	70.0pq	6.	PH1	59.7				
7.	PC	58.9ghijk	65.0lmnop	68.8op	75.0qr	7.	PC	66.9				
8.	PB	61.3ijklm	65.0lmnop	66.3mnop	78.8rs	8.	PB	67.8				
9.	PG2	47.5b	63.8klmno	67.5nop	80.0rst	9.	PG2	68.0				
10.	PD	62.2jklm	77.8rs	81.1st	92.2v	10.	PD	78.7				
11.	PE	48.0bcd	51.3bcdef	100.0w	100.0w	11.	PE	77.7				
12.	PH2b	60.0hijkl	85.0tu	90.0uv	100.0w	12.	PH2b	83.8				
P < 0.0000						P < 0.0000			P < 0.0000			

Comparison between sampling points between the orchards

- Only for orchard F, no significant difference in the incidence of lenticel damage occurred between the four sampling points, with the incidence varying between 30 - 32.5%.
  The finding implicates that lenticel damage was not induced by additional steps in the handling chain for this producer and orchard.
- For the remaining 11 orchards, incidence of lenticel damage was significantly lower for fruit picked and packed directly into boxes in the orchard (Box pick), compared to fruit moved through the entire handling chain and packed after sorting in the pack-house (Pack-line).
  The finding implicates that lenticel incidence was ± 20% higher on fruit exposed to the full handling chain, compared to fruit packed directly in 2 orchards (B & C), while ± 30% higher for 6 orchards (A, D, G1, G3, H1 & H2a), 40% higher for 2 orchards (G2 & H2b) and ± 50% higher for 1 orchard (E).
- For 10 of the 12 orchards (A, C, D, E, G1, G2, G3, H1, H2a & H2b), excluding orchards F & B, incidence of lenticel damage was also significantly lower for fruit picked and packed directly into boxes in the orchard (Box picked), compared to fruit picked by the farm and then into boxes upon arrival at the pack-house, without subjecting the fruit to the pack-line (arrival at pack-house)
  The finding implicates that lenticel incidence was ± 10% higher on fruit exposed to the handling chain until arrival at the pack-house, compared to fruit packed directly in 8 orchards (A, C, D, G1, G2, G3, H1 & H2b), while remaining ± 50% higher for orchard E.
- For 6 orchards (A, C, D, G1, G2 & H2b) incidence of lenticel damage was significantly higher than the remaining orchards (B, E, F, G3, H1 & H2a) for fruit picked by the farm and packed into boxes in the orchard, without subjecting the fruit to the remainder of the handling chain (Farm pick), compared to fruit picked and packed directly into boxes in the orchard (Box picked).
  The finding implicates that lenticel incidence was ± 10% higher on fruit exposed to farm picking compared to fruit packed directly in orchard C, while ± 20% higher for 4 orchards (A, D, G1 & G2), while 30% higher for orchard H2b.

Comparison between orchards for each of the sampling points

- For fruit picked by an individual directly into boxes (Box picked), or picked by the farm and packed into boxes by an individual (Farm picked), lenticel damage was significantly lower for 7 producers (A, E, G1,

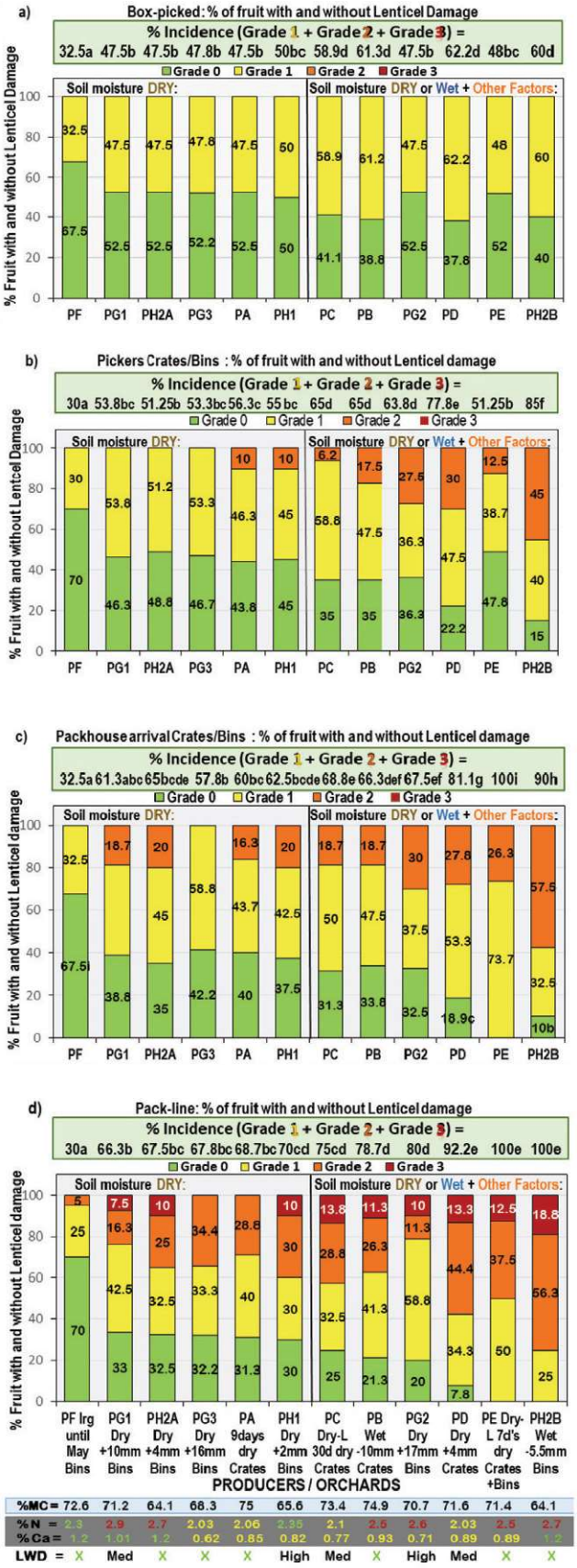

Figure 3: Percentage fruit with lenticel damage for samples procured from 12 'Hass' avocado orchards from (a) box-picked fruit (b) picking teams harvest (c) from the bins upon arrival at the pack-house and (d) from the pack-line. The intensity of the disorder was quantified using PPECB's grading system (Grade 0, 1, 2 & 3). The producer code, soil moisture and sampling point is indicated. Stats: ANOVA; Fisher LSD P<0.05

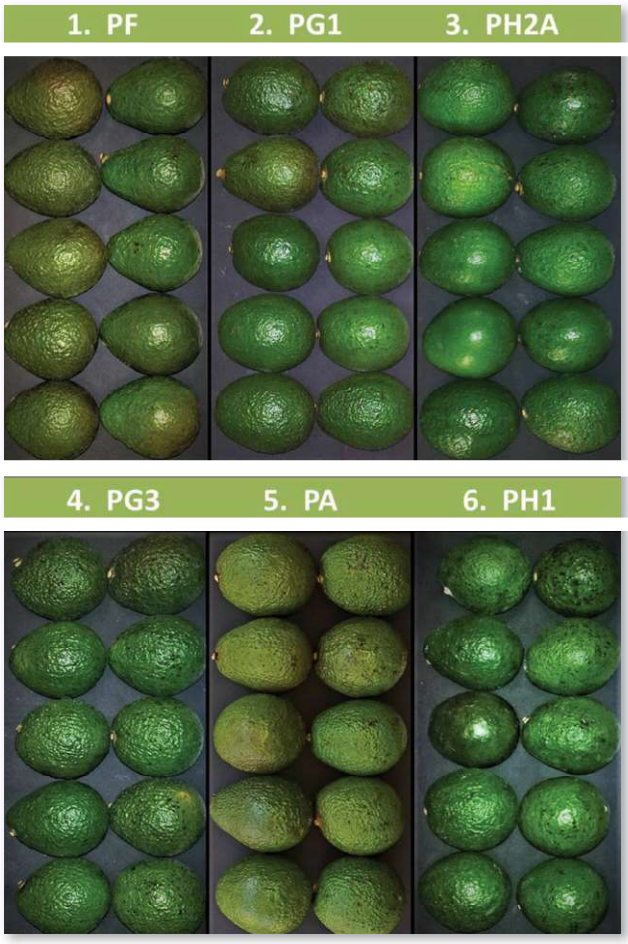

Figure 4: Visual appearance class 1 export quality fruit (25 days cold storage) of producer F, G1, H2a, G3, A & H1, sampled from the pack-line

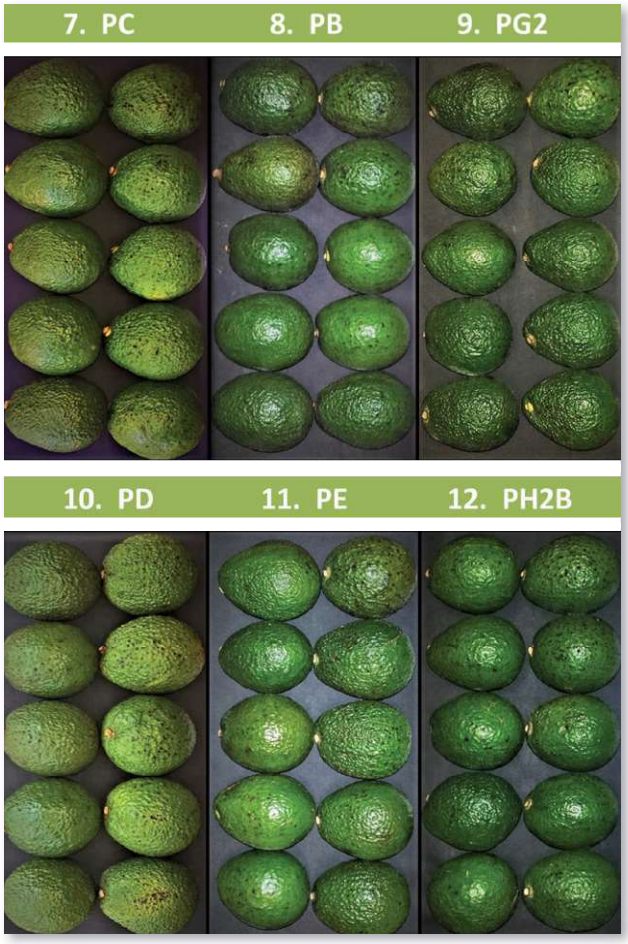

Figure 5: Visual appearance of class 1 export quality fruit (25 days cold storage) of producer C, B, G2, D, E and H2b, sampled from the pack-line

G2, G3, H1 & H2a) compared to fruit picked and packed similarly by the 4 remaining producers (B, C, D & H2b).

- Similarly, fruit picked by the farm and packed by an individual upon arrival at the pack-house (Pack-house arrival), or picked by the farm and packed after subjecting to the pack-line, lenticel damage was significantly lower for 8 producers (A, B, C, G1, G2, G3, H1 & H2a), compared to fruit picked and packed similarly by the 3 remaining producers (D, E & H2b).

  The findings implicate that the incidence of lenticel damage is influenced by the number of handling processes practiced, which differ on a farm/orchard level.

General observations/comments relating to Table 2 & 3 and Figure 3, 4 & 5, as related to the level of lenticel damage

- The producer of **orchard F** irrigated until the end of May, after which it basically became a dry-land orchard for a month, until harvest on 7 July. Due to water shortage on this farm the producer was forced to stop irrigation, however irrigation was slowly reduced to ensure the trees were not stressed. This orchard was the only one where the bulk of the fruit exhibited no lenticel damage (Grade 0) at all sampling points (Fig. 3a - d). The lower lenticel damage can be associated with a longer soil drying period, allowing the skin of the fruit to adapt and cell walls to harden prior to harvest. The N : Ca ratio was optimal, not leading to continuous cell division and thin cell walls. Furthermore, the handling practices followed were good and hence lenticel damage remained at the same level as when harvested and packed in the orchard.
- **Orchards G1, G2 and G3**, all of the same producer, were selected as being of a "dry soil moisture" (G1 = +10 mm probe reading, G2 = +17 mm and G3 = +16 mm). Although, G2 was harvested at a "dry soil moisture" of +17 mm, higher cumulative incidence of 80% was obtained across Grade 1, 2 and 3, compared to ± 66.25% for G2 harvested at +16 mm (Fig. 3). The high incidence of lenticel damage for G2 can be ascribed to conditions of high wind, late in the season, occurring at orchard G2, and not at G1 and G3. Late wind damage is similar to lenticel damage, causing brown-black lesions. It was noted that most Grade 3 damage due to late wind damage was not removed during sorting on the pack-line. Lenticel damage increased as the fruit of all orchards were subjected to additional handling, however, more so for orchard G2 than G1 & G3.

- The cumulative lenticel damage incidence of **orchards H2a and H2b**, of the same producer, differed by almost 40%, with the highest level exhibited for orchard H2b. This can be ascribed to the difference in soil moisture levels at harvest for the two fruit samples, with H2a an orchard of a "drier soil moisture" (+4 mm) and orchard H2b a "wet soil moisture" (-6 mm). Adherence to the industry soil moisture protocol resulted in much lower lenticel damage. Furthermore, lenticel damage increased as the fruit of both orchards were subjected to additional handling, however, more so for orchard H2b. Lenticel damage for **orchard H1** of the same producer was of a moderate level, most likely due to not adhering completely to the soil moisture protocol, as the fruit were harvested at a probe reading of +2 mm, not allowing for sufficient drying before harvest. Lenticel damage increased as the fruit of all orchards were subjected to additional handling, however, more so for orchard H2b, exhibiting much higher levels of Grade 2 and 3 on fruit sampled from the pack-line, being exposed to multiple handling phases.
- **Orchard A** was selected as being of a "dry soil moisture", although probes were not used. This orchard was not irrigated in the month prior to harvest due to high rainfall (102 mm in total) that occurred during this month, with 9 d of no rain prior to harvest. Lenticel damage increased as the fruit were subjected to additional handling, reaching a level of ± 34% for each of Grade 1 and 2 on fruit sampled from the pack-line.
- **Orchard C** was selected as being of a "dry soil moisture" of a dry-land orchard. No rain occurred within 30 d prior to harvest. Lenticel damage of ± 60% was exhibited on fruit subjected to minimal handling, by harvesting and packing fruit in the orchard. This orchard was considered to be part of the "Group B" category, based on the level of lenticel damage exhibited, also as a result of low N (2.1) and low leaf Ca (0.77). The relative high level of damage is ascribed to the moderate wind conditions experienced, as well as excessive stress conditions occurring by dry-land cultivation of a low N orchard during a dry season year of low rainfall. The likelihood of increased susceptibility of low calcium with thin fruit skin to develop lenticel damage cannot be excluded. It has been shown by Lemmer (2007) that low leaf Ca may lead to premature senescence of the skin surrounding the lenticels during mid- to late season.
- **Orchard B** was selected as being of a "wet soil moisture". Probe readings of -10 mm were recorded. Lenticel damage of ± 60% was exhibited on fruit subjected to minimal handling, by harvesting and packing fruit in the orchard. Damage increase by ± 15% as additional handling practices followed before sampling of fruit.
- **Orchard D** was initially selected as being of a "dry soil moisture" with a probe reading of +4 mm at time of harvest. Despite irrigation being stopped 2 w prior to harvest, leading to a probe reading of +4 mm, irrigation taps were accidentally opened 1 d prior to harvest, decreasing the soil moisture to +1 mm, increasing the following day back to +4 mm. To be considered is the fact that the soil dried out 2 weeks prior to harvest, and that although opening the irrigation taps did not decrease the soil moisture beyond field capacity into a negative value, sufficient moisture was present to be absorbed and hence increase the turgor within the fruit skin cells. Moderate wind further contributed to skin damage. Lenticel damage of 60% was exhibited on fruit subjected to minimal handling, increasing to ± 90% when sampled from the pack-line, indicating extensive and rough handling of fruit, with ± 14% Grade 3 damage exhibited on fruit. The low leaf N and Ca levels could also have negatively impacted on cell wall strength.
- **Orchard E** was selected as being of a "dry soil moisture" of a dry-land orchard, supposedly of Group A orchards, including 7 d of no rain prior to harvest. Lenticel damage of ± 48% was exhibited on fruit subjected to minimal handling, by harvesting and packing fruit in the orchard, however, damage increased to 100% as fruit were subjected to additional handling practices during transport to the pack-house and on the pack-line after harvest. Hence, this orchard was included in the Group B orchards due to the high level of lenticel damage. The reason for the high level of damage being extensive handling, as this producer washed and pre-sorted the fruit on-farm on a small pack-line in a secondary pack-house, followed by transport on a stretch of a 5 km bumpy dirt road and another 38 km before reaching the final pack-house.

Suggestions / comments

- Soil moisture needs to be managed appropriately, by using industry protocols, to enforce a proper dry-out period prior to harvest.
- Travel distance to the pack-house should be minimised, especially on bumpy gravel roads, hence avoiding fruit vibration and damage to the skin.
- N : Ca ratios should be optimised, to support healthy and hardy cell walls.
- Fruit should be handled with care during harvesting, and thereafter, to ensure that sound, undamaged fruit reaches the pack-house.
- Packing should be gentle, to avoid damage to the fruit skin and development of lenticel damage during storage.

Means of reducing physical and abrasion damage during transport to the pack-house:

- Minimise distance that bins are moved by forklifts in the field.
- Bins should be loaded with utmost care, without dropping bins or bashing each other.
- Farm roads should be well kept by regular grading and filling potholes.
- Re-routing trucks to avoid roads in a bad condition.
- Slower driving to avoid excessive vibration and harsh braking.
- Use trucks fitted with air suspension to reduce vibration.
- Reduce tyre air pressure (Dakar, 1991).

Table 4: Rationale behind dividing 12 'Hass' producers/orchards into two main groups, according to pre-harvest practices followed prior to, during and at picking, relating to the level of lenticel damage recorded after storage

Groups		Orchard		Producers with probes Soil Moisture at picking	Days No Rain	Comments / Other factors that played a role	Incidence of Late Wind Damage	Leaf N	Leaf Ca
Group A	Dry Soil Moisture	1.	PF	-	7	No probes; Irrigation stopped 1 m; rain thereafter, however 7d no rain prior to picking; optimum N:Ca ratio; Cautious handling from pick to pack; No wind	No	2.30	1.20
		2.	PG1	+10 mm	-	Probes; Adherence to soil moisture protocol; High N, though optimum Ca, assisting with cell wall strength / properties; Acceptable wind	Low	2.90	1.01
		3.	PH2a	+4 mm	-	Probes; Adherence to soil moisture protocol; High N, though optimum Ca, assisting with cell wall strength / properties; No wind	No	2.70	1.21
		4.	PG3	+16 mm	-	Probes; Adherence to soil moisture protocol, dry at picking; Low N; No wind	No	2.03	0.62
		5.	PA	-	9	No probes; Irrigation stopped 1 m prior to pick; Rain thereafter, however 9 d no rain prior to picking; Below acceptable N:Ca ratio; No wind	No	2.06	0.85
		6.	PH1	+2 mm	-	Probes; Adherence to soil moisture protocol; Dry picking, however could improve; optimum N:Ca ratio, assist in cell development and strength; Fair amount of wind, causing moderate superficial damage and countering the adherence to protocol	Moderate	2.35	0.82
Group B	Wet Soil Moisture or other factors affecting superficial damage negatively	7.	PC	-	30	No probes; Dry-land orchard; 30 d no rain prior to picking; Low N; Fair amount of wind causing moderate superficial damage, countering dry soil picking by increased fruit skin senescence of a low nitrogen dry-land orchard produced during a low rainfall season and hence increasing possibility of damage; Fair amount of wind, causing moderate superficial damage	Moderate	2.10	0.77
		8.	PB	-10 mm	-	Probes; No adherence to soil moisture protocol; High N, though optimum Ca; No wind	No	2.50	0.93
		9.	G2	+17 mm	-	Probes; Adherence to soil moisture protocol; Dry conditions, however, negated by extreme wind conditions causing increased superficial skin and lenticel damage; High N refuting the adherence to the soil moisture protocol	High	2.60	0.71
		10.	PD	+4 mm	-	Probes; Adherence to soil moisture protocol, However, irrigation taps were opened accidentally 1 d prior to pick, increasing soil moisture from +4 mm to +1 mm; Fair amount of wind causing increased superficial skin and lenticel damage	Moderate	2.03	0.89
		11.	PE	-	7	No probes. Dry-land orchard-; 7 d no rain prior to picking; High N; No wind; Rough and extensive handing during and after picking (pre-sort fruit on farm in a small pack-line)	No	2.50	0.89
		12.	PH2b	-6 mm	-	Probes; No adherence to soil moisture protocol; Wet picking; High N, though optimum Ca; No wind	No	2.68	1.21

Group A included orchards that were harvested within SAAGA soil moisture recommendation to minimise lenticel damage
Group B included orchards that were harvested with soils too wet, or other factors influencing the incidence of lenticel damage negatively, such as Nitrogen and Calcium content, as well as the incidence of late wind damage

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Table 5: Leaf, fruit pulp and fruit skin nutrient values, including Nitrogen (N), Calcium (Ca), Magnesium (Mg) and Boron (B) of 12 orchards

		Leaf, pulp and skin nutrient values											
		N %			Ca %			Mg %			B mg/kg		
Producer / Orchard		Leaf (2.2)	Pulp	Skin	Leaf (1-2)	Pulp	Skin	Leaf (0.4-0.8)	Pulp	Skin	Leaf (50-80)	Pulp	Skin
Dry Soil moisture	F	2.30	0.45	0.76	1.20	0.10	0.18	0.50	0.14	0.18	50.0	82.4	107.6
	G1	2.90	0.76	0.93	1.01	0.10	0.17	0.41	0.13	0.17	14.0	37.9	48.2
	H2a	2.70	0.49	0.95	1.21	0.09	0.16	0.60	0.12	0.16	54.0	99.0	116.4
	G3	2.03	0.41	0.90	0.62	0.05	0.17	0.47	0.10	0.17	14.0	42.6	39.1
	A	2.06	0.79	1.06	0.85	0.10	0.13	0.60	0.15	0.18	-	26.6	35.3
	H1	2.35	0.37	0.86	0.82	0.07	0.15	0.44	0.08	0.15	50.0	92.6	119.3
Dry or Wet Soil Moisture + Other Factors	C	2.10	0.72	1.01	0.77	0.08	0.16	0.4	0.13	0.16	16.0	48.9	20.0
	B	2.50	1.30	1.17	0.93	0.05	0.15	0.46	0.13	0.15	57.0	74.6	112.6
	G2	2.60	0.45	0.88	0.71	0.06	0.15	0.47	0.10	0.15	16.0	44.5	35.5
	D	2.03	0.55	1.13	0.89	0.08	0.18	0.53	0.11	0.18	19.0	37.0	42.6
	E	2.50	0.63	0.81	0.89	0.06	0.16	0.46	0.13	0.16	16.0	43.5	59.0
	H2b	2.68	0.49	0.95	1.21	0.09	0.16	0.60	0.12	0.16	54.0	99.0	116.4

Table 6: Incidence of Anthracnose and stem-end rot of 'Hass' avocado fruit of 12 orchards for the difference between Box-picked at harvest and fruit sampled from the Pack-line

QUALITY PARAMETER – ANTHRACNOSE								
Factor A (Orchard) x Factor B (Sampling point)				Factor A (Orchard)			Factor B (Handling)	
Orchard		Box-Picked	Pack-line				Box-Picked	Pack-line
1.	F	5.0	5.0	1.	F	5.0ab	6.8	8.2
2.	G1	5.0	3.8	2.	G1	4.8ab		
3.	H2a	5.0	3.8	3.	H2a	4.8ab		
4.	G3	5.6	6.7	4.	G3	6.1ab		
5.	A	7.5	5.0	5.	A	6.3ab		
6.	H1	5.0	2.5	6.	H1	3.8ab		
7.	C	3.3	2.2	7.	C	2.8a		
8.	B	13.8	17.5	8.	B	15.6c		
9.	G2	5.0	7.5	9.	G2	6.3ab		
10.	D	11.1	16.6	10.	D	13.9c		
11.	E	10.0	17.5	11.	E	13.7c		
12.	H2b	5.0	10.0	12.	H2b	7.5b		
		P < 0.1390				P < 0.0000	P < 0.0820	

QUALITY PARAMETER – STEM-END ROT								
Factor A (Orchard) x Factor B (Handling)				Factor A (Orchard)			Factor B (Handling)	
Orchard		Box-picked	Pack-line				Box-picked	Pack-house
1.	F	0.0	5.0	1.	F	2.5a	8.3	7.6
2.	G1	7.5	10.0	2.	G1	8.8bcd		
3.	H2a	5.0	3.8	3.	H2a	4.4ab		
4.	G3	8.9	10.0	4.	G3	9.4cd		
5.	A	6.3	7.5	5.	A	6.9abcd		
6.	H1	6.3	3.8	6.	H1	5.0abc		
7.	C	7.8	7.8	7.	C	7.8bcd		
8.	B	15.0	16.3	8.	B	15.6e		
9.	G2	10.0	7.5	9.	G2	8.8bcd		
10.	D	10.0	8.9	10.	D	9.4cd		
11.	E	5.0	16.3	11.	E	10.6d		
12.	H2b	6.3	6.3	12.	H2b	6.3abcd		
		P < 0.2040				P < 0.000	P < 0.5260	

* Letters that are similar do not differ significantly, according to Fisher LSD (α = 0.05)

Incidence of lenticel damage in relation to fruit maturity/ pulp moisture content (Fig. 6)

- Lenticel damage did not correlate to the fruit pulp moisture content.

Incidence of lenticel damage in relation to soil moisture content (Fig. 7)

- Lenticel damage did not correlate linearly to soil moisture.
- However, the lowest lenticel damage occurred for orchards G3 & G1, with probe readings of +16 mm and +10 mm, respectively.

Leaf, fruit skin and fruit pulp nutrient content in relation to lenticel damage (Table 5)

- Generally, nutrients of leaves, fruit skin and fruit pulp were not a good indicator of lenticel damage.
- However, in some instances, such as orchard F with optimum N (2.3%), Ca (1.2%), Mg (0.5%) and B (50 mg/kg), the lowest lenticel damage of 30% was exhibited.
- Fruit of low and high N, as well as low Ca levels generally exhibited higher lenticel damage.
- It is known that calcium provides improved cell wall integrity and hence reduces lenticel damage (Polevoiy, 1989). It is also known that chelated calcium, magnesium and boron are needed for cell wall development and fruit set and that boron encourages the uptake and movement of cation nutrients such as Mg and Ca within the plant (Plich & Wojcik, 2008).

Incidence of lenticel damage in relation to Anthracnose decay (Fig. 8 and Table 6)

Figure 8

- Generally, decay from Anthracnose was higher on fruit of Group B (wet soil moisture or factors), especially when the fruit were exposed to more handling stages (fruit sampled in the pack-house compared to fruit harvested and packed directly into boxes).
- The incidence of Anthracnose was highest on fruit of orchard B (of a wet soil moisture), orchard D (accidental irrigation

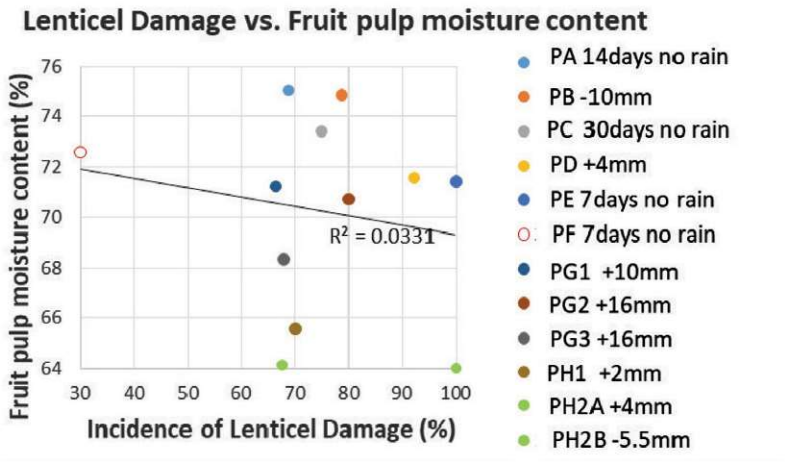

Figure 6: Incidence of lenticel damage in relation to the fruit pulp moisture at harvest of fruit procured from 12 orchards

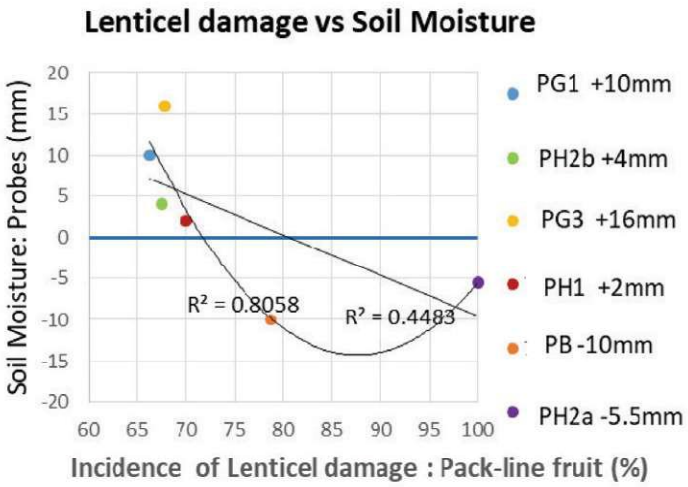

Figure 7: Incidence of lenticel damage in relation to soil moisture content at harvest of fruit procured from 12 orchards

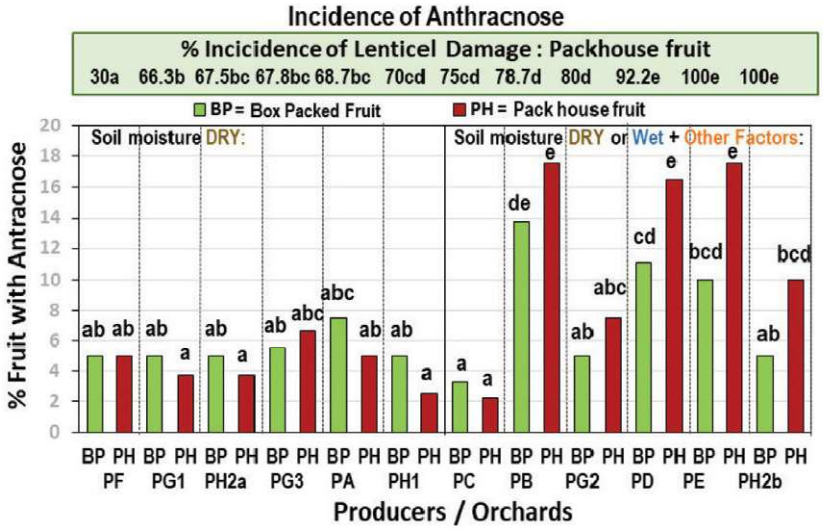

Figure 8: Incidence of Anthracnose on fruit procured from the pack-line, as well as fruit that were box-picked in the orchard, of 12 orchards. Letters that are dissimilar are significantly different according to Fisher's LSD (α = 0.05)

1 day prior to harvest) and orchard E (extensive handling of fruit in the pack-house).
- The incidence of Anthracnose is highly dependent on the inherent inoculum load in the orchard and the application of timeous fungicide sprays.

Table 6
- No interaction occurred between Factor A (orchard) and Factor B (handling stage) for Anthracnose development. Significant differences were indicated between orchards.
- Anthracnose was significantly higher on fruit from orchards D and E, compared to most other orchards (A, B, C, F, G1, G2, G3, H1, H2a & H2b); Orchard D (accidental irrigation 1 day prior to harvest) and orchard E (extensive handling of fruit in the pack-house).
- Furthermore, Anthracnose was significantly higher on fruit from orchards B and H2b, compared to orchard C; Orchard B and H2b (wet soil moisture), while orchard C (dry-land orchard).
- Sampling point of fruit, related to additional handling when sourced from the pack-line, compared to minimal handling when sourced in the orchard, did not influence Anthracnose.

Incidence of lenticel damage in relation to stem-end rot (Table 6)
- No interaction occurred between Factor A (orchard) and Factor B (handling stage) for stem-end rot development. Significant differences were indicated between orchards.
- Stem-end rot was significantly higher on fruit of orchard B (probe reading of -10 mm for soil moisture) compared to all other orchards.
- Stem-end rot was significantly lower on fruit of orchard F compared to all most orchards, except orchards H2a, A, H1 & H2b.

Incidence of bruising (Fig. 9 and Table 7)
Figure 9
- Generally, bruising is a function of how careful picking is done.
- The incidence of bruising was highest for fruit of orchard D

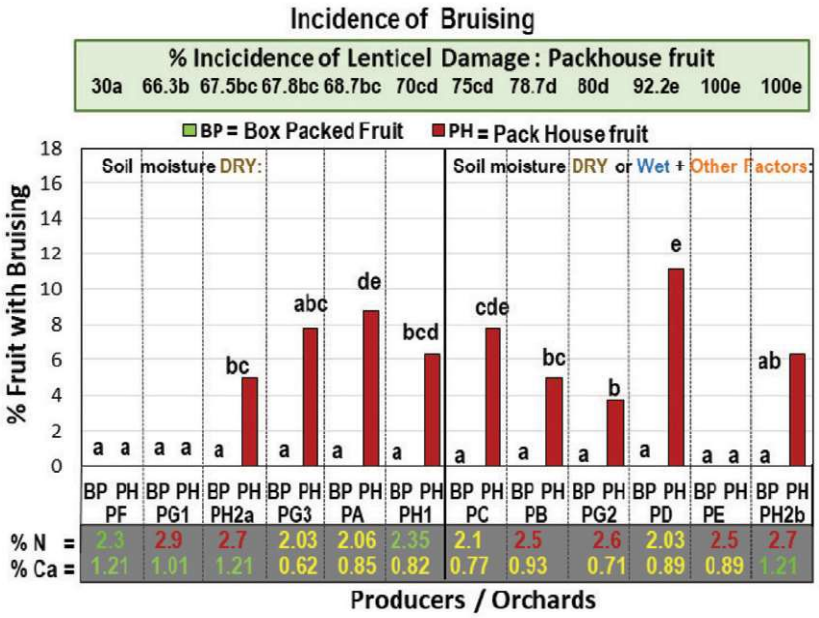

Figure 9: Incidence of bruising on fruit procured from the pack-line, as well as fruit that were box-picked in the orchard, of 12 orchards. Letters that are dissimilar are significantly different according to Fisher's LSD (α = 0.05)

(accidental irrigation 1 day prior to harvest), on fruit sampled in the pack-house compared to fruit harvested and packed directly into boxes.

Table 7
- A significant interaction occurred between Factor A (orchard) and Factor B (handling stage) for bruising.
- No difference occurred between orchards for fruit picked and packed in the orchard.
- Bruising differed between orchards for fruit sampled from the pack-line.
- Bruising was significantly less on fruit of orchards F and G1, compared to all other orchards, which corresponds to fruit with the lowest lenticel damage; orchard F (irrigation stopped 1 month prior to harvest and meticulous handling throughout the handling chain); orchard G1 (adherence to soil moisture protocol (+10 mm probe reading) and optimum leaf Ca).
- Bruising was significantly lower for 9 of the 12 orchards (A, B, C, D, E, G2, G3, H1 & H2a; but not F, G1 & H2b) for fruit sampled in the orchard immediately after harvest, compared to fruit sampled from the pack-line.
- The results indicated that additional handling of avocado induces bruising significantly.

Number of days for fruit to ripen (Table 7)
- No interaction occurred between Factor A (orchard) and Factor B (handling stage) for days for fruit to ripen. Significant differences were indicated between orchards.
- Fruit from orchards H2a, H1 an H2b ripened significantly faster (less number of days) compared to most other orchards.

Incidence of grey pulp (Table 8)
- No grey pulp was recorded on avocados from any orchard.

Incidence of vascular browning (Table 8)
- A significant interaction occurred between Factor A (orchard) and Factor B (handling stage) for bruising.
- Vascular browning was significantly less on fruit sampled immediately after harvest for orchards F and H2a, compared to orchards A, D, E, G1 and G3. The results indicated that soil moisture at harvest did not relate to vascular browning after storage.






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- Vascular browning was significantly less on fruit sampled from the pack-line for orchards G3 and H2b, compared to orchards A, B, C, D, E, G1 & G3.
- Vascular browning was significantly lower for only 2 of the 12 orchards (F & H2b) for fruit sampled in the orchard immediately after harvest, compared to fruit sampled from the pack-line.
- The results indicated that soil moisture at harvest did not relate to vascular browning after storage.

Analyses of data subsequent to the primary analyses

To emphasise differences in lenticel damage more clearly between picking and handling practices on a producer level, orchards were sorted according to the average level of lenticel damage (from low to high), obtained by the first Two-way ANOVA assessment, with pre-harvest and at harvest practices listed as possible reasons for differences in lenticel damage. Consequently it was evident that lenticel damage associated with specific orchards and practices followed, could be divided into two main groups, Group A – picking according to the criteria of "Dry soil moisture conditions" and Group B – picking according to "Wet soil moisture conditions or other factors influencing superficial damage to the fruit skin" (Table 4).

Subsequent to the first analyses, data were subjected to the following analyses

i) Two-way ANOVA of 12 orchards, and Two-way ANOVA of 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling

Table 7: Incidence of Bruising and Number of days for fruit to ripen (DTR) of 'Hass' avocado fruit of 12 orchards for the difference between Box-picked at harvest and fruit sampled from the Pack-line

QUALITY PARAMETER – BRUISING								
Factor A (Orchard) x Factor B (Sampling point)				Factor A (Orchard)			Factor B (Handling)	
Orchard		Box-Picked	Pack-line				Box-Picked	Pack-line
1.	F	0.0a	0.0a	1.	F	0.0a	0.0a	5.5b
2.	G1	0.0a	0.0a	2.	G1	0.0a		
3.	H2a	0.0a	5.0bc	3.	H2a	2.5ab		
4.	G3	0.0a	7.8cde	4.	G3	3.9bc		
5.	A	0.0a	8.8de	5.	A	4.4bc		
6.	H1	0.0a	6.3bcd	6.	H1	3.1bc		
7.	C	0.0a	7.8cde	7.	C	3.9bc		
8.	B	0.0a	5.0bc	8.	B	2.5ab		
9.	G2	0.0a	3.8b	9.	G2	1.9ab		
10.	D	0.0a	11.1e	10.	D	5.6c		
11.	E	0.0a	5.0bc	11.	E	2.5ab		
12.	H2b	0.0a	6.3bcd	12.	H2b	3.1bc		
		P < 0.0010				P < 0.0010	P < 0.0000	

QUALITY PARAMETER – No OF DAYS TO RIPEN (DTR)								
Factor A (Orchard) x Factor B (Handling)				Factor A (Orchard)			Factor B (Handling)	
Orchard		Box-picked	Pack-line				Box-picked	Pack-house
1.	F	5.4	5.3	1.	F	5.3d	5.2	5.2
2.	G1	5.6	5.6	2.	G1	5.6fg		
3.	H2a	4.4	4.6	3.	H2a	4.5a		
4.	G3	5.2	5.2	4.	G3	5.2cd		
5.	A	5.7	5.7	5.	A	5.7g		
6.	H1	4.7	4.7	6.	H1	4.7b		
7.	C	5.6	5.5	7.	C	5.5f		
8.	B	5.4	5.3	8.	B	5.3de		
9.	G2	5.4	5.3	9.	G2	5.4e		
10.	D	5.5	5.3	10.	D	5.4ef		
11.	E	5.1	5.1	11.	E	5.3de		
12.	H2b	4.6	4.6	12.	H2b	4.6ab		
		P < 0.6280				P < 0.0000	P < 0.5830	

* Letters that are similar do not differ significantly, according to Fisher's LSD (α = 0.05)

points "box picked" and "farm picked" (Table 9).

ii) Two-way ANOVA of 12 orchards, and Two-way ANOVA of 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "box picked" and "packed upon arrival at pack-house" (Table 10).

iii) Two-way ANOVA of 12 orchards, and Two-way ANOVA of 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "box picked" and "packed on the pack-line" (Table 11).

iv) Two-way ANOVA of 12 orchards, and Two-way ANOVA of 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "farm picked" and "packed upon arrival at pack-house" (Table 12).

v) Two-way ANOVA of 12 orchards, and Two-way ANOVA of 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "farm picked" and "packed on the pack-line" (Table 13).

vi) Two-way ANOVA of 12 orchards, and Two-way ANOVA of 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "packed upon arrival at pack-house" and "packed on the pack-line" (Table 14).

Table 8: Incidence of Grey-pulp and Vascular browning of 'Hass' avocado fruit of 12 orchards for the difference between Box-picked at harvest and fruit sampled from the Pack-line

QUALITY PARAMETER – GREY PULP								
Factor A (Orchard) x Factor B (Sampling point)				Factor A (Orchard)			Factor B (Handling)	
Orchard		Box-Picked	Pack-line				Box-Picked	Pack-line
1.	F	0.0	0.0	1.	F	0.0	0.0	0.0
2.	G1	0.0	0.0	2.	G1	0.0		
3.	H2a	0.0	0.0	3.	H2a	0.0		
4.	G3	0.0	0.0	4.	G3	0.0		
5.	A	0.0	0.0	5.	A	0.0		
6.	H1	0.0	0.0	6.	H1	0.0		
7.	C	0.0	0.0	7.	C	0.0		
8.	B	0.0	0.0	8.	B	0.0		
9.	G2	0.0	0.0	9.	G2	0.0		
10.	D	0.0	0.0	10.	D	0.0		
11.	E	0.0	0.0	11.	E	0.0		
12.	H2b	0.0	0.0	12.	H2b	0.0		
		-				-	-	

QUALITY PARAMETER – VASCULAR BROWNING								
Factor A (Orchard) x Factor B (Handling)				Factor A (Orchard)			Factor B (Handling)	
Orchard		Box-picked	Pack-line				Box-picked	Pack-house
1.	F	0.0a	5.0bcde	1.	F	2.5ab	6.4	5.6
2.	G1	15.0g	12.5fg	2.	G1	13.75e		
3.	H2a	1.3ab	0.0a	3.	H2a	0.6cd		
4.	G3	7.8de	4.4bcd	4.	G3	6.1cd		
5.	A	7.5de	8.8ef	5.	A	8.1d		
6.	H1	5.0bcde	2.5abc	6.	H1	3.8bc		
7.	C	4.4bcd	6.7de	7.	C	5.6cd		
8.	B	5.0bcde	7.5 de	8.	B	6.3cd		
9.	G2	5.0bcde	2.5abc	9.	G2	3.8bc		
10.	D	5.6cde	4.4bcd	10.	D	5.0bc		
11.	E	15.0g	12.5fg	11.	E	13.8e		
12.	H2b	5.0bcde	0.0a	12.	H2b	2.5ab		
		P < 0.0230				P < 0.000	P < 0.1610	

* Letters that are similar do not differ significantly, according to Fisher's LSD (α = 0.05)

DISCUSSION

i) Two-way ANOVA of 12 orchards, and Two-way ANOVA of 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "box picked" and "farm picked" (Table 9)

A significant interaction occurred between Factor A (orchard) and Factor B (sampling points), where 12 orchards were compared, as well as 6 orchards for Group A and 6 orchards for Group B.

Note: Findings will only be discussed within and across 12 orchards.

Within "box-picked fruit" and "farm picked" across 12 orchards

- For fruit picked by an individual directly into boxes (Box picked), or picked by the farm and packed into boxes by an individual (Farm picked), lenticel damage was significantly lower for orchard F compared to all other orchards.
- Furthermore, at both sampling points, lenticel damage was significantly lower for orchards A, E, G1, G3, H1 and H2a, compared to orchards B, C, D and H2b.

Table 9: Incidence of lenticel damage on fruit of 12 'Hass' orchards, sampled at 2 points; (a) after personalised box pick and pack and (b) in the orchard from bins after farm picked, presenting Two-way ANOVA on 12 orchards, and Group A and Group B orchards

QUALITY PARAMETER – LENTICEL DAMAGE								
Factor A (Orchard) x Factor B (Sampling points)				Factor A (Orchards)			Factor B (Sampling points)	
Orchard		(a) After box pick	(b) After farm pick				(a) After box pick	(b) After farm pick
1.	F	32.5a	30.0a	1.	F	31.3a	50.9a	58.9b
2.	G1	47.5b	53.8cde	2.	G1	49.4b		
3.	H2a	47.5b	51.3bcd	3.	H2a	49.6b		
4.	G3	47.8b	53.3cde	4.	G3	50.7b		
5.	A	47.5b	56.3efg	5.	A	50.6b		
6.	H1	50.0ab	55.0def	6.	H1	51.9b		
7.	C	58.9fgh	65.0j	7.	C	52.5bc		
8.	B	61.3hij	65.0j	8.	B	55.6c		
9.	G2	47.5b	64.4ij	9.	G2	61.9d		
10.	D	62.2hij	77.8k	10.	D	63.1d		
11.	E	48.0b	51.3bcd	11.	E	70.0e		
12.	H2b	60.0ghi	85.0l	12.	H2b	72.5e		
		P<0.0000				P<0.0000	P < 0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – DRY SOIL MOISTURE								
1.	F	32.5a	30.0a	1.	F	31.3a	56.3a	68.0b
2.	G1	47.5b	53.8ab	2.	G1	49.4b		
3.	H2a	47.5b	51.3bcd	3.	H2a	50.6b		
4.	3	47.8b	53.3cde	4.	3	50.6b		
5.	A	47.5b	56.3e	5.	A	51.9b		
6.	H1	50.0bc	56.3e	6.	H1	52.5b		
		P<0.0000				P<0.0000	P < 0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – WET SOIL MOISTURE or DRY SOIL MOISTURE PLUS OTHER FACTORS								
7.	C	58.9b	65.0d	7.	C	49.6a	50.9a	58.9b
8.	B	61.3bcd	65.0d	8.	B	55.6b		
9.	G2	47.5a	64.4cd	9.	G2	61.9c		
10.	D	62.2bcd	77.8e	10.	D	63.1c		
11.	E	48.0a	51.3a	11.	E	70.0d		
12.	H2b	60.0bc	85.0f	12.	H2b	72.5d		
		P<0.0000				P < 0.0000	P < 0.0000	

* Letters that are dissimilar are significantly based on the Fisher's LSD (α = 0.05)

PICKLOGGER™

AVOCADOS

Picklogger™ is a harvesting tool that records the location of every fruit harvested. This data is then used to produce quantity and fruit yield maps.. Recorded data is used to produce fruit yield maps.

This valuable data can be combined with other farm-related information, such as results from leaf analyses, type of soils, satellite imagery of the farm and crops, data from soil moisture probes, and the physical and chemical properties of these soils. By integrating these different layers of information producers can make sound data-driven farming decisions.

HOW TO USE

The number of fruit harvested per field, per management unit or per tree is used to generate yield maps and to provide information on the spatial variation in yield. Producers can respond to these variations **to optimise production.**

Near real-time picking maps are generated and made available on **MYFARMWEB™**, ensuring quick and easy visualisation and comparison to previous maps. This data can be combined with other agronomic information (soil physical classification, soil chemical analysis, leaf analysis, satellite imagery, soil moisture probes, etc.) and accessed on a single platform. This provides the producer with different layers of information on his farming operations, which is necessary for **holistic data-driven management decisions.**

Picklogger™ provides information on the picking activity of a harvester. It provides **data for comparative labour-related statistics.**

Accurate spatial yield data provides valuable insights in the relationship between field variability, crop management and crop response, for **improved operations management decisions.**

Picklogger™ data provides information for in-orchard interventions, for **increased yield and return on investment for the producer.**

All information available on **MYFARMWEB™** for easier visualisation and the ability to combine several sources of agronomic information in one place, for informed decision making.

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www.laeveld.co.za

Table 10: Incidence of lenticel damage on fruit of 12 'Hass' orchards, sampled at 2 points; (a) after personalised box pick and pack, and (c) upon arrival at the pack-house, presenting Two-way ANOVA on 12 orchards, and Group A and Group B orchards

QUALITY PARAMETER – LENTICEL DAMAGE								
Factor A (Orchard) x Factor B (Sampling points)				Factor A (Orchards)			Factor B (Sampling points)	
Orchard		(a) After box pick	(c) Upon arrival at pack-house				(a)After box pick	(c) Upon arrival at pack-house
1.	F	32.5a	32.5a	1.	F	32.5a	50.9a	67.8b
2.	G1	47.5b	61.3cde	2.	G1	52.8b		
3.	H2a	47.5b	65.0defg	3.	H2a	53.8b		
4.	G3	47.8b	57.8c	4.	G3	54.4bc		
5.	A	47.5b	60.0cd	5.	A	56.3bc		
6.	H1	50.0b	62.5cdef	6.	H1	56.3bc		
7.	C	58.9c	68.8g	7.	C	57.5c		
8.	B	61.3cde	66.3efg	8.	B	63.8d		
9.	G2	47.5b	67.5fg	9.	G2	63.8d		
10.	D	62.2cde	81.1h	10.	D	71.7e		
11.	E	48.0b	100.0j	11.	E	74.0e		
12.	H2b	60.0cd	90.0i	12.	H2b	75.0e		
		P<0.0000				P<0.0000	P<0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – DRY SOIL MOISTURE								
1.	F	32.5a	32.5a	1.	F	32.5a	45.5a	56.5b
2.	G1	47.5b	61.3cd	2.	G1	52.8b		
3.	H2a	47.5b	65.0cd	3.	H2a	53.8b		
4.	3	47.8b	57.8c	4.	G3	54.4b		
5.	A	47.5b	60.0cd	5.	A	56.3b		
6.	H1	50.0b	62.5cd	6.	H1	56.3b		
		P<0.0020				P<0.0000	P<0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – WET SOIL MOISTURE or DRY SOIL MOISTURE PLUS OTHER FACTORS								
7.	C	58.9b	68.8d	7.	C	63.9b	56.3a	78.9b
8.	B	61.3b	66.3cd	8.	B	63.8b		
9.	G2	47.5a	67.5d	9.	G2	57.5a		
10.	D	62.2bc	81.1e	10.	D	71.7c		
11.	E	48.0a	100.0g	11.	E	74.0cd		
12.	H2b	60.0b	90.0f	12.	H2b	75.0e		
		P<0.0000				P < 0.0000	P<0.0000	

* Letters that are dissimilar are significantly based on the Fisher's LSD (α = 0.05)

Across "box-picked fruit" and "farm picked" for 12 orchards

- Lenticel damage was significantly lower in "Box picked" than "Farm picked" fruit for 9 of the orchards (A, B, C, D, G1, G2, G3, H1 and H2b), however similar for orchards F, H2a and E.

ii) Two-way ANOVA of 12 orchards, 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "box picked" and "packed upon arrival at pack-house" (Table 10)

A significant interaction occurred between Factor A (orchard) and Factor B (sampling points), where 12 orchards were compared, as well as 6 orchards for Group A and 6 orchards for Group B.

Note: Findings will only be discussed within and across 12 orchards.

Within "box-picked fruit" and "packed upon arrival" across 12 orchards

- For fruit picked by an individual directly into boxes (Box picked), or packed on arrival at the packhouse (On arrival pack), lenticel damage was significantly lower for orchard F compared to all other orchards.
- Furthermore, at both sampling points, lenticel damage was significantly lower for orchards A, G1, G2, G3, H1 and H2a, compared to orchards D and H2b.

Table 11: Incidence of lenticel damage on fruit of 12 'Hass' orchards, sampled at 2 points; (a) after personalised box pick and packed, and (d) from the pack-line, presenting Two-way ANOVA on 12 orchards, and Group A and Group B orchards

QUALITY PARAMETER – LENTICEL DAMAGE								
Factor A (Orchard) x Factor B (Sampling points)				Factor A (Orchards)			Factor B (Sampling points)	
Orchard		(a) After box pick	(d) From pack-line				(a) After box pick	(d) From pack-line
1.	F	32.5a	30.0a	1.	F	31.3a	50.9a	74.7b
2.	G1	47.5b	66.3defg	2.	G1	56.9b		
3.	H2a	47.5b	67.5efg	3.	H2a	57.5b		
4.	G3	47.8b	67.8efg	4.	G3	57.8b		
5.	A	47.5b	68.8fgh	5.	A	58.1b		
6.	H1	50.0b	70.0gh	6.	H1	60.0bc		
7.	C	58.9c	75.0hi	7.	C	66.9de		
8.	B	61.3cde	78.8i	8.	B	70.0ef		
9.	G2	47.5b	80.0i	9.	G2	63.8cd		
10.	D	62.2cdef	92.2j	10.	D	77.2gh		
11.	E	48.0a	100.0k	11.	E	74.0fg		
12.	H2b	60.0cd	100.0k	12.	H2b	80.0h		
		P<0.0000			**P<0.0000**		**P<0.0000**	
QUALITY PARAMETER – LENTICEL DAMAGE – DRY SOIL MOISTURE								
1.	F	32.5a	30.0a	1.	F	31.3a	45.5a	61.7b
2.	G1	47.5b	66.3c	2.	G1	56.9b		
3.	H2a	47.5b	67.5c	3.	H2a	57.5b		
4.	3	47.8b	67.8c	4.	3	57.8b		
5.	A	47.5b	68.8c	5.	A	58.1b		
6.	H1	50.0b	70.0c	6.	H1	60.0b		
		P<0.0004			**P<0.0000**		**P<0.0000**	
QUALITY PARAMETER – LENTICEL DAMAGE – WET SOIL MOISTURE or DRY SOIL MOISTURE PLUS OTHER FACTORS								
7.	C	58.9b	75.0c	7.	C	66.9ab	56.3a	87.7b
8.	B	61.3b	78.8c	8.	B	70.0b		
9.	G2	47.5a	80.0c	9.	G2	63.8a		
10.	D	62.2b	92.2d	10.	D	77.2cd		
11.	E	48.0a	100.0e	11.	E	74.0c		
12.	H2b	60.0b	100.0e	12.	H2b	80.0d		
		P<0.0000			**P < 0.0000**		**P<0.0000**	

* Letters that are dissimilar are significantly based on the Fisher's LSD (α = 0.05)

Table 12: Incidence of lenticel damage on fruit of 12 'Hass' orchards, sampled at 2 points; (b) in the orchard from bins after farm picked, and (c) upon arrival at the pack-house, presenting Two-way ANOVA on 12 orchards, and Group A and Group B orchards

QUALITY PARAMETER – LENTICEL DAMAGE								
Factor A (Orchard) x Factor B (Sampling points)				Factor A (Orchards)			Factor B (Sampling points)	
	Orchard	(b) After farm pick	(c) Upon arrival at pack-house				(b) After farm pick	(c) Upon arrival at pack-house
1.	F	30.0a	32.5a	1.	F	31.3a	67.7a	74.7b
2.	G1	53.8bc	61.3efg	2.	G1	55.6b		
3.	H2a	51.3b	65.0ghi	3.	H2a	57.5bc		
4.	G3	53.3bc	57.8cde	4.	G3	58.1bc		
5.	A	56.3cd	60.0def	5.	A	58.1bc		
6.	H1	56.3cd	62.5efgh	6.	H1	59.4c		
7.	C	65.0ghi	68.8i	7.	C	65.6d		
8.	B	65.0ghi	66.3hi	8.	B	65.9d		
9.	G2	64.4fghi	67.5i	9.	G2	66.9d		
10.	D	77.8j	81.1jk	10.	D	75.6e		
11.	E	51.3b	100.0m	11.	E	79.4f		
12.	H2b	85.0k	90.0l	12.	H2b	87.5g		
		P<0.0000				P<0.0000	P<0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – DRY SOIL MOISTURE								
1.	F	30.0a	32.5a	1.	F	31.3a	56.50a	61.71b
2.	G1	53.8bc	61.3def	2.	G1	55.6b		
3.	H2a	51.3b	65.0f	3.	H2a	57.5b		
4.	3	53.3bc	57.8cde	4.	G3	58.1b		
5.	A	56.3bcd	60.0def	5.	A	58.1b		
6.	H1	56.3bcd	62.5ef	6.	H1	59.4b		
		P<0.0000				P<0.0000	P<0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – WET SOIL MOISTURE or DRY SOIL MOISTURE PLUS OTHER FACTORS								
7.	C	65.0b	68.8c	7.	C	71.9a	78.9a	87.7b
8.	B	65.0b	66.3bc	8.	B	72.5a		
9.	G2	64.4b	67.5bc	9.	G2	73.8a		
10.	D	77.8d	81.1b	10.	D	86.7b		
11.	E	51.3a	100.0g	11.	E	95.0c		
12.	H2b	85.0e	90.0f	12.	H2b	100.0d		
		P<0.0000				P < 0.0000	P<0.0000	

* Letters that are dissimilar are significantly based on the Fisher's LSD (α = 0.05)

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Table 13: Incidence of lenticel damage on fruit of 12 'Hass' orchards, sampled at 2 points; (b) in the orchard from bins after farm picked, and (d) from the pack-line, presenting Two-way ANOVA on 12 orchards, and Group A and Group B orchards

QUALITY PARAMETER – LENTICEL DAMAGE								
Factor A (Orchard) x Factor B (Sampling points)				Factor A (Orchards)			Factor B (Sampling points)	
	Orchard	(b) After farm pick	(d) From pack-line				(b) After farm pick	(d) From pack-line
1.	F	30.0a	30.0a	1.	F	30.0a	59.1a	74.7b
2.	G1	53.8b	66.3c	2.	G1	60.0b		
3.	H2a	51.3b	67.5c	3.	H2a	59.4b		
4.	G3	53.3b	67.8c	4.	G3	60.6b		
5.	A	56.3b	68.8cd	5.	A	62.5b		
6.	H1	55.0b	70.0cd	6.	H1	63.1b		
7.	C	65.0c	75.0cd	7.	C	70.0c		
8.	B	65.0c	78.8ef	8.	B	71.9cd		
9.	G2	63.8c	80.0ef	9.	G2	72.2cd		
10.	D	77.8e	92.2g	10.	D	85.0e		
11.	E	51.3b	100.0h	11.	E	75.6d		
12.	H2b	85.0f	100.0h	12.	H2b	92.5f		
		P<0.0000			P<0.0000		P<0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – DRY SOIL MOISTURE								
1.	F	30.0a	30.0a	1.	F	30.0a	50.1a	61.7b
2.	G1	53.8b	66.3c	2.	G1	60.0b		
3.	H2a	51.3b	67.5c	3.	H2a	59.4b		
4.	G3	53.3b	67.8c	4.	3	60.6b		
5.	A	56.3b	68.8c	5.	A	62.5b		
6.	H1	55.0b	70.0c	6.	H1	63.1b		
		P<0.0079			P<0.0000		P<0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – WET SOIL MOISTURE or DRY SOIL MOISTURE PLUS OTHER FACTORS								
7.	C	65.0b	75.0c	7.	C	70.0a	68.1a	87.7b
8.	B	65.0b	78.8cd	8.	B	71.9a		
9.	G2	64.4b	80.0d	9.	G2	72.2a		
10.	D	77.8cd	92.2f	10.	D	85.0c		
11.	E	51.3a	100.0g	11.	E	75.1b		
12.	H2b	85.0e	100.0g	12.	H2b	92.5d		
		P<0.0000			P < 0.0000		P<0.0000	

* Letters that are dissimilar are significantly based on the Fisher's LSD (α = 0.05)

Across "box-picked fruit" and "packed upon arrival" for 12 orchards

- Lenticel damage was significantly lower in "Box picked" than "Farm picked" fruit for 11 of the orchards (A, B, C, D, E, G1, G2, G3, H1, H2a and H2b), however similar for orchard F.

iii) Two-way ANOVA of 12 orchards, 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "box picked" and "from the pack-line" (Table 11)

A significant interaction occurred between Factor A (orchard) and Factor B (sampling points), where 12 orchards were compared, as well as 6 orchards for Group A and 6 orchards for Group B.

Note: Findings will only be discussed within and across 12 orchards.

Within "box-picked fruit" and "packed by pack-line" across 12 orchards

- For fruit picked by an individual directly into boxes (Box picked), or packed by the pack-line (Pack-line), lenticel damage was significantly lower for orchard F compared to all other orchards.
- Furthermore, at both sampling points, lenticel damage was significantly lower for orchards A, G1, G3, H1 and H2a, compared to orchards B, D and H2b.

Across "box-picked fruit" and "packed by pack-line" for 12 orchards

- Lenticel damage was significantly lower in "Box picked" than "Farm picked" fruit for 11 of the orchards (A, B, C, D, E, G1, G2, G3, H1, H2a and H2b), however similar for orchard F.

iv) Two-way ANOVA of 12 orchards, 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "farm picked" and "upon arrival at the pack-house" (Table 12)

A significant interaction occurred between Factor A (orchard) and Factor B (sampling points), where 12 orchards were compared, as well as 6 orchards for Group A and 6 orchards for Group B.

Note: Findings will only be discussed within and across 12 orchards.

Within "farm picked" and "packed upon arrival" across 12 orchards

- For fruit picked by the farm and packed by an individual in the orchard, (Farm picked), or packed upon arrival at the pack-house (Upon arrival), lenticel damage was significantly lower for orchard F compared to all other orchards.
- Furthermore, at both sampling points, lenticel damage was significantly lower for orchards A, G1, G3 and H1, compared to orchards B, C, D, G2 and H2b.

Across "farm picked" and "packed upon arrival" for 12 orchards

- Lenticel damage was significantly lower in "Farm picked" than "Packed upon arrival" fruit for 6 of the orchards (D, E, G1, H1, H2a and H2b), however similar for orchards A, B, C, F, G2 and G3.

v) Two-way ANOVA of 12 orchards, 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "farm picked" and "from the pack-line" (Table 13)

A significant interaction occurred between Factor A (orchard) and Factor B (sampling points), where 12 orchards were compared, as well as 6 orchards for Group A and 6 orchards for Group B.

Note: Findings will only be discussed within and across 12 orchards.

Within "farm picked" and "packed on the pack-line" across 12 orchards

- For fruit picked by the farm and packed by an individual in the orchard, (Farm picked), or packed at the pack-house on the pack-line (Packed by pack-line), lenticel damage was significantly lower for orchard F compared to all other orchards.
- Furthermore, at both sampling points, lenticel damage was significantly lower for orchards A, G1, G3, H1 and H2a, compared to orchards B, D, G2, and H2b.

Across "farm picked" and "packed upon arrival" for 12 orchards

- Lenticel damage was significantly lower in "Farm picked" than "Packed upon arrival" fruit for 6 of the orchards (D, E, G1, H1, H2a and H2b), however similar for orchards A, B, C, F, G2 and G3.

vi) Two-way ANOVA of 12 orchards, 6 orchards for Group A and 6 orchards for Group B, for comparison between the sampling points "upon arrival at pack-house" and "from the pack-line" (Table 14)

A significant interaction occurred between Factor A (orchard) and Factor B (sampling points), where 12 orchards were compared, as well as 6 orchards for Group A and 6 orchards for Group B.

Note: Findings will only be discussed within and across 12 orchards.

Within "Packed upon arrival at pack-house" and "packed on the pack-line" across 12 orchards

- For fruit picked by the farm and packed by an individual upon arrival at the pack-house (Upon arrival packed), or packed at the pack-house on the pack-line (Packed by pack-line), lenticel damage was significantly lower for orchard F compared to all other orchards.
- Furthermore, at both sampling points, lenticel damage was significantly lower for orchards A, G1, G3 and H1, compared to orchards B, D, G2 and H2b.

Across "Packed upon arrival at pack-house" and "packed on the pack-line" for 12 orchards

- Lenticel damage was significantly lower in "Packed upon arrival" than "Packed on the pack-line" fruit for 7 of the orchards (A, B, D, G2, G3, H1 and H2b), however similar for orchards C, E, F, G1 and H2a.

Table 14: Incidence of lenticel damage on fruit of 12 'Hass' orchards, sampled at 2 points; (c) upon arrival at the pack-house, and (d) from the pack-line, presenting Two-way ANOVA on 12 orchards, and Group A and Group B orchards

QUALITY PARAMETER – LENTICEL DAMAGE								
Factor A (Orchard) x Factor B (Sampling points)				Factor A (Orchards)			Factor B (Sampling points)	
Orchard		(c) Upon arrival at pack-house	(d) From pack-line				(c) Upon arrival at pack-house	(d) From pack-line
1.	F	32.5a	30.0a	1.	F	31.3a	50.9a	58.9b
2.	G1	61.3bcd	66.3cdef	2.	G1	63.8b		
3.	H2a	65.0cdef	67.5def	3.	H2a	66.3b		
4.	G3	57.8b	67.8def	4.	G3	62.8b		
5.	A	60.0bc	68.8efg	5.	A	64.4b		
6.	H1	62.5bcde	70.0fg	6.	H1	66.3b		
7.	C	68.8efg	75.0gh	7.	C	71.9c		
8.	B	66.3cdef	78.8h	8.	B	72.5c		
9.	G2	67.5def	80.0h	9.	G2	73.8c		
10.	D	81.1h	92.2i	10.	D	86.7d		
11.	E	100.0j	100.0j	11.	E	95.0e		
12.	H2b	90.0i	100.0j	12.	H2b	100.0f		
		P<0.0000				P<0.0000	P<0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – DRY SOIL MOISTURE								
1.	F	32.5a	30.0a	1.	F	31.3a	56.3a	68.0b
2.	G1	61.3bcde	66.3bcde	2.	G1	63.8b		
3.	H2a	65.0bcde	67.5cde	3.	H2a	66.3b		
4.	G3	57.8b	67.8cde	4.	G3	62.8b		
5.	A	60.0bc	68.8de	5.	A	63.4b		
6.	H1	62.5bcde	70.0e	6.	H1	66.25		
		P<0.0000				P<0.0000	P<0.0000	
QUALITY PARAMETER – LENTICEL DAMAGE – WET SOIL MOISTURE or DRY SOIL MOISTURE PLUS OTHER FACTORS								
7.	C	68.8a	75.0b	7.	C	49.6a	50.9a	58.9b
8.	B	66.3a	78.8bc	8.	B	55.6b		
9.	G2	67.5a	80.0bc	9.	G2	61.9c		
10.	D	81.1c	92.2d	10.	D	63.1c		
11.	E	100.0e	100.0e	11.	E	70.0d		
12.	H2b	90.0d	100.0e	12.	H2b	72.5d		
		P<0.0000				P < 0.0000	P<0.0000	

* Letters that are dissimilar are significantly based on the Fisher's LSD (α = 0.05)

Table 15: Ca and N content in fruit pulp and fruit skin, 3 weeks after conducting the 3rd spray of different $Ca(NO_3)_2$ dose rates in an orchard of low nitrogen

Treatments		N%		Ca%	
		Pulp	Skin	Pulp	Skin
T1	water	0.44	0.71	0.08	0.12
T2	0.20% $Ca(NO_3)_2$	0.55	1.02	0.10	0.10
T3	0.35% $Ca(NO_3)_2$	0.74	1.06	0.08	0.11
T4	0.50% $Ca(NO_3)_2$	0.78	1.13	0.09	0.12

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TRIAL 2 – FOLIAR APPLICATION OF CALCIUM NITRATE IN A LOW NITROGEN ORCHARD

A foliar treatment of calcium nitrate was applied in a low nitrogen orchard, in an attempt to increase nitrogen and calcium content in 'Hass' avocado fruit skin. The effect of such treatment on fruit quality was assessed after storage of fruit handled with care and fruit "jostled" to enhance damage.

Findings

N and Ca levels in fruit (Table 15)

- Calcium nitrate foliar applications increased N levels in both the pulp and skin of avocado fruit.
- The highest N values were obtained for the 0.5% $Ca(NO_3)_2$ dose rate.
- N levels were generally higher in the skin than in the pulp of fruit.
- In contrast, calcium nitrate foliar applications did not influence Ca levels in either the pulp or skin of avocado.
- Findings of researchers differ with regard to the response of pre-harvest N or Ca applications in fruit. Domagała-Świątkiewicz & Błaszczyk (2007) indicated a decrease of N/Ca and K/Ca ratios in harvested apple, while Lotze *et al.* (2008) found an increase of Ca in apple by late applications of $Ca(NO_3)_2$. Saucedo-Hernández (2003) indicated enhanced fruit firmness and reduced fruit weight loss of 'Fuerte' avocado treated pre-harvest with 0.3 and 0.5 % $Ca(NO_3)_2$, while CO_2 and ethylene production, polyphenoloxidase enzyme (PPO) activity and chilling injury were lower on treated fruits.

Fruit quality assessment following $Ca(NO_3)_2$ applications (Table 16)

Lenticel damage

- A significant interaction occurred between Factor A (handling of fruit by jostling or not) and Factor B (application of $Ca(NO_3)_2$ at different dose rates).
- Incidence of lenticel damage was significantly higher on jostled fruit compared to fruit not jostled, irrespective of $Ca(NO_3)_2$ dose rate.
- Lenticel damage increased significantly as $Ca(NO_3)_2$ dose rate was increased for avocado jostled prior to packing. Lenticel damage was significantly higher for application of $Ca(NO_3)_2$ at a dose rate of 0.5% (T4), compared to the lower dose rates of T1, T2 and T3 on avocado not jostled prior to packing.

Table 16: Fruit quality for samples procured from a low nitrogen orchard where $Ca(NO_3)_2$ sprays were applied at dosages of 0, 0.2, 0.35 and 5% (T1-T4), and subsequently at harvest the fruit were either subjected to a treatment of "jostling" to induce lenticel damage or left intact prior to packing. The intensity of the disorder was quantified using PPECB's grading system (Grade 0 = sound, Grade 1, Grade 2 and Grade 3)

QUALITY PARAMETER – LENTICEL DAMAGE											
Factor A (Jostle) x Factor B ($Ca(NO_3)_2$ Treatments)						Factor A (Jostle)			Factor B ($Ca(NO_3)_2$ Treatments)			
	Jostle	T1	T2	T3	T4				T1	T2	T3	T4
1.	Not Jostled	52.2ab	55.6bc	51.1a	56.7c	1.	Not Jostled	53.8	57.2	64.5	65.6	71.2
2.	Jostled	62.2d	73.3e	80.0f	85.6g	2.	Jostled	75.3				
		P < 0.000				P <0.000			P < 0.000			
QUALITY PARAMETER – ANTHRACNOSE												
1.	Not Jostled	13.3	13.3	12.2	12.2	1.	Not Jostled	13.1a	13.3	15.6	15.6	16.6
2.	Jostled	13.3	14.4	18.9	21.1	2.	Jostled	17.5b				
		P < 0.175				P <0.006			P < 0.489			
QUALITY PARAMETER – STEM-END ROT												
1.	Not Jostled	14.0	15.6	18.9	18.9	1.	Not Jostled	15.6	14.2	15.6	18.9	15.6
2.	Jostled	14.4	15.6	18.9	13.3	2.	Jostled	16.6				
		P <0.462				P <0.422			P <0.065			
QUALITY PARAMETER – GREY PULP												
1.	Not Jostled	0.0	0.0	0.0	0.0	1.	Not Jostled	0.0	0.0	0.0	0.0	0.0
2.	Jostled	0.0	0.0	0.0	0.0	2.	Jostled	0.0				
		-				-			-			
QUALITY PARAMETER – VASCULAR BROWNING												
1.	Not Jostled	8.9	11.1	10.0	7.8	1.	Not Jostled	9.4	8.3	10.6	10.0	8.3
2.	Jostled	7.8	10.0	7.8	8.9	2.	Jostled	9.2				
		P < 0.884				P < 0.810			P < 0.403			
QUALITY PARAMETER – No OF DAYS TO RIPEN												
1.	Not Jostled	4.5	4.4	4.4	4.4	1.	Not Jostled	4.4	4.5	4.4	4.4	4.4
2.	Jostled	4.4	4.4	4.4	4.4	2.	Jostled	4.4				
		P < 0.205				P <0.205			P < 0.197			

* Letters that are dissimilar are significantly based on the Fisher's LSD (α = 0.05)

Anthracnose

- No interaction occurred between Factor A (handling of fruit by jostling or not) and Factor B ($Ca(NO_3)_2$ application).
- Anthracnose was significantly higher on jostled compared to not-jostled fruit.
- Albeit not significantly, Anthracnose increased as the dose rate of $Ca(NO_3)_2$ was increased for fruit jostled prior to packing.

Stem-end rot, Grey pulp, vascular browning and Number of days required for fruit to ripen

- Stem-end rot, Grey pulp, vascular browning and Number of days required for fruit to ripen, was not significantly influenced by either jostling or $Ca(NO_3)_2$ application at different dose rates.

Suggestions / comments

- Late season applications of $Ca(NO_3)_2$ did not reduce lenticel damage, but rather increased damage, especially when handled without care.
- Anthracnose increases on fruit handled inappropriately, especially if $Ca(NO_3)_2$ dose rates are increased.
- Nitrogen levels were increased in fruit pulp and skin, but not calcium.
- Nitrogen is known to increase growth and cell division, resulting in thin skin cell walls.
- It is advised not to apply nutrients known to increase nitrogen levels at a late stage of fruit development, and not to handle such fruit roughly at time of picking and packing, since susceptibility to lenticel damage, as well as anthracnose decay, may increase.

CONCLUSIONS

- The incidence of lenticel damage was in most instances (11 of the 12 orchards) directly associated with handling during picking, transport and packing, increasing as additional practices were included during the handling chain, varying between 60 - 100% on fruit after storage, when sampled from the pack-line.
- Grade 3, extensive damage according to the PPECB lenticel grading protocol, only occurred on fruit sampled from the pack-line.
- Lenticel damage can to an extent be regarded as "cumulative", with damage increasing as processes are added along the handling chain.
- The findings imply that handling fruit with care during harvesting, transport and packing is essential to ensure that less damage develop during storage.
- Travel distance to the pack-house should be minimised, especially on bumpy gravel roads, hence avoiding fruit vibration and damage to the skin.
- Pedicels should be cut short, preferably before placement into picking bags.
- Proper training, consistent and stringent supervision needs to be enforced throughout the handling chain. Lenticel damage was lowest where effective picking and packing teams worked in a well-organised manner, ensuring minimised handling and damage to fruit.
- A significant finding during this 2019 study was that most producers surveyed do not adhere to the important protocol of "Avoid picking from orchards with soils at field capacity, as this could increase susceptibility to lenticel damage". Harvesting fruit at "drier" soil moisture was shown to be a major factor in reducing lenticel damage. Producers who were forced and stopped irrigating 1 month prior to harvest, due to water shortages, showed 70% sound fruit, 25% Grade 1 and 5% Grade 2 damage with no Grade 3 damage recorded.
- Considering the finding of lower lenticel damage associated with forced stopping of irrigation, the question arises, does the industry not over-irrigate? Literature clearly states that irrigation cycles should be adjusted according to soil type and needs at specific growth stages. Soil of high clay content needs to dry to +20 mm before the next irrigation, whereas ideal soil should dry down to only +5 mm.
- Soil moisture needs to be managed appropriately, by using industry protocols, to enforce a proper dry-out period prior to harvest.
- Incidence of lenticel damage was significantly higher on avocado subjected to "jostling" (manhandled by tumbling in a bucket) prior to packing.
- Lenticel damage increased significantly as the preharvest $Ca(NO_3)_2$ dose rate was increased, especially on jostled fruit.
- Anthracnose increased significantly on fruit subjected to manhandling and was higher albeit not significantly, on fruit treated with $Ca(NO_3)_2$ at a higher dose rate.
- Late applications of $Ca(NO_3)_2$ should be avoided, since lenticel damage was not reduced, but rather increased, especially when avocado are handled without care.
- N : Ca ratios should be optimised, to support healthy and hardy cell walls.
- It is clear from the findings pertaining to irrigation and fertilisation, that these issues warrant further research.

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