RESEARCH TOWARDS REDUCING THE INCIDENCE OF LENTICEL DAMAGE OF SOUTH AFRICAN 'HASS' EXPORT AVOCADO FRUIT

D Lemmer, HW Viljoen and JF Fourie

ExperiCo, Agri-Research Solutions,
PO Box 4022, Idas Valley, Stellenbosch 7609, SOUTH AFRICA

E-mail: danie@experico.co.za

ABSTRACT

Two orchards of optimum leaf N, Ca and B levels, exhibited less lenticel damage compared to high nitrogen orchards of 2020. The irrigation treatment of 5 weeks with no irrigation prior to harvest did not reduce the incidence of lenticel damage compared to the optimum full irrigation treatment, when applied to a high nitrogen orchard. This finding rejects the possibility of this irrigation protocol, being the main contributing factor in reducing the incidence of lenticel damage. Trees in an orchard studied in 2019 with optimal leaf N, Ca, Mg and B were able to accumulate B in the fruit skin with a value that was ± 100% higher than the leaf B value obtained from fruits with the least lenticel damage. This partly explains this orchard's remarkable resistance to develop lenticel damage. This very high skin B content could only have been obtained with optimum photosynthetic output in place, to ensure the availability of Perseitol (a C7 sugar) that acts as carrier of B during phloem transport. An orchard studied in 2020 with optimal leaf N, Ca, Mg and B very similar to the orchard studied in 2019 which obtained the least lenticel damage, in contrast could only accumulate B in the fruit skin with a value that was only ± 6 higher than the leaf B value. This implicates that photosynthetic output was inhibited during fruit development. This led to less Perseitol available to act as carrier, which influenced the effective and optimum phloem transport of B to the fruit skin. Further research is needed to verify this important finding. This possibly led to reduced fruit skin integrity that explains the higher tendency to develop lenticel damage. Suboptimal irrigation may limit the root uptake of Ca and B through transpiration, and hence limit the integrity of the fruit skin, adding to increased sensitivity to lenticel damage. This emphasises the importance of optimum irrigation during the first 6 - 7 weeks of fruit development to ensure that Ca and B accumulate optimally in the fruit skin. The three foliar spray combinations of Ca + B applied with two Si + B combination nutrient foliar sprays 3 months prior to harvest, reduced the total incidence of lenticel damage on 'Hass' avocado by ± 13%, despite the fruit being procured from a high nitrogen orchard. The findings warrant further research, with view in refining the best application, timing and number of applications, with a focus on Si treatments to improve Ca and B absorption into the pulp and skin of 'Hass' avocado. The beneficial effect of Si soil applications in preceding Si foliar sprays also needs to be studied.

INTRODUCTION

The avocado industry identified the need for research solutions to reduce lenticel damage. Lenticel damage, a disorder of the peel of avocados, manifests as brown or black spots on the fruit skin. This disorder occurs when the fruit skin is damaged in the region around the lenticels. When the fruit skin is fully turgid (not wilted), the lenticels become sensitive and highly susceptible to handling damage. It was requested that time be spent on farms to identify pre-harvest factors, as well as harvest practices, that could possibly relate to the occurrence of lenticel damage. The brief was to critically ascertain if producers adhere to the current industry protocols to reduce lenticel damage and to determine the influence of pre-harvest nutritional factors in the expression of skin/pulp nutrient composition and subsequent lenticel damage.

Lenticel damage was in the past mainly perceived to be a problem in 'Fuerte' avocados, showing unsightly brown or black speckles on fruit staying green when ripe. 'Hass', in contrast, was perceived to be of a lower risk in developing lenticel damage, since lenticel damage is hardly visible once the fruit has coloured and ripened, despite possibly harboring lenticel damage when green, prior to colour transformation. Competition in the market has changed the

perception towards lenticel damage, with the buyer rather selecting 'Hass' with no visible lenticel damage. Results of the 2nd year's study of a 3-year project are reported on.

Three main objectives were identified for the 2020 season:

1. To investigate the effect of irrigation regimes on high nitrogen and optimum nitrogen orchards on lenticel damage during storage of 'Hass' avocado.
2. To investigate if reduced irrigation followed by 5 weeks of no irrigation prior to harvest, provides protection/resistance towards the reduction of lenticel damage in an orchard of a high nitrogen level (proved to be sensitive to lenticel damage in 2019).
3. To ascertain if late nutrient foliar applications of calcium, boron and silicon, 3 months prior to harvest, effectively manifested in the fruit skin and if these could assist in reducing lenticel damage in an orchard with a high nitrogen level.

MATERIALS AND METHODS

Taking the results of 2019 into consideration, research for 2020 was redirected taking important findings of 2019 into consideration and to prove the validity of certain findings. Three trials were conducted.

TRIAL 1: The effect of irrigation protocol on high nitrogen and optimum nitrogen orchards, on lenticel damage during storage of 'Hass' avocado – Objective 1

Treatments

The original trial layout was to irrigate 1x high nitrogen and 1x of the optimal nitrogen orchard according to the "Reduced irrigation" schedule and 1x high nitrogen and 1x optimal nitrogen orchard according to the "Full sprinkler irrigation" schedule.

Deviation from anticipated protocol: Orchard selection had to be adapted. Only "full sprinkler irrigation" was applied by two of the producers of choice, since the trees already started to flower and the reduction in fruit load was not an option to consider. As an alternative, an optimum nitrogen orchard with reduced irrigation that utilises drag-line irrigation was identified. However, no high nitrogen orchards that utilise drag-line irrigation were available to include in the study.

Five orchards of 2 producers were visited in 2020, which were harvested and evaluated:

2 x high nitrogen orchards of Producer I (2020):

- Orchard IS2A (leaf nutritional composition: N = 2.58%, Mg = 0.56%, Ca = 1%, B = 37 mg/kg)
  - The nutritional composition represented an orchard of: high N, optimum Ca and Mg, slightly low B
  - Full sprinkler irrigation; wet soil moisture prior to harvest
- Orchard IS3A (leaf nutritional composition: N = 2.74%, Mg = 0.55%, Ca = 1%, B = 46 mg/kg)
  - The nutritional composition represented an orchard of: high N, optimum Ca and Mg, slightly low B
  - Full sprinkler irrigation; wet soil moisture prior to harvest.

2 x optimum nitrogen orchards of Producer I (2020):

- Orchard IS1B (leaf nutritional composition: N = 2.25%, Mg = 0.60%, Ca = 1.1%, B = 56 mg/kg)
  - The nutritional composition represented an orchard of: optimum N, optimum Ca, Mg and B (this nutritionally optimum orchard was very similar to orchard F, exhibiting low lenticel damage in 2019)
  - Full sprinkler irrigation; dry soil moisture prior to harvest
- Orchard I43B (leaf nutritional composition: N = 2.3%, Mg = 0.52%, Ca = 0.87, B = 46 mg/kg)
  - The nutritional composition represented an orchard of: optimum N, optimum Mg, slightly low Ca and B
  - Drag line irrigation (receiving ± 1/3 of the volume of water compared to optimum sprinkler irrigation); dry soil moisture period prior to harvest.

1 x high nitrogen orchard of Producer G:

- 2020 leaf nutritional composition: N = 2.9%, Mg = 0.41%, Ca = 1.01%, B = 22.9 mg/kg
  - Full sprinkler irrigation; dry soil moisture prior to harvest.

Four other orchards where fruits were harvested in 2019 were included for study purposes:

1 x nutritionally optimum orchard of Producer F (selected in 2019):

- F1 (2019 leaf nutritional composition: N = 2.3%, Mg = 0.50%, Ca = 1.2%, B = 50 mg/kg)
  - The nutritional composition represented an orchard of: optimum N, optimum Ca, Mg and B (fruits from this orchard could not be harvested in 2020, since the orchard was heavily pruned and almost no fruits were available. The orchard will be revisited in 2021
  - Full sprinkler irrigation; dry soil moisture prior to harvest (7 days no rain).

2 x high nitrogen orchards of Producer H (selected in 2019, harvested at wet and dry soil moisture):

- H2A (2019 leaf nutritional composition: N = 2.68%, Mg = 0.60%, Ca = 1.21%, B = 54 mg/kg)
  - The nutritional composition represented an orchard of: high N, optimum Ca, Mg and B
  - Full sprinkler irrigation; dry soil moisture prior to harvest
- H2B (2019 leaf nutritional composition: N = 2.68%, Mg = 0.60%, Ca = 1.21%, B = 54 mg/kg)
  - The nutritional composition represented an orchard of: high N, optimum Ca, Mg and B

- Full sprinkler irrigation; wet soil moisture prior to harvest.

1 x high nitrogen orchard of Producer G (for study purposes the 2019 results of this orchard were also included):

- G1 (2019 leaf nutritional composition: N = 2.9%, Mg = 0.55%, Ca = 1.01%, B = 14 mg/kg)
  - An orchard of: optimum N, optimum Ca and Mg, very low B
  - Full sprinkler irrigation; dry soil moisture prior to harvest.

Harvest and cold storage:

- Samples were taken from 4 sampling points during the handling chain (5 box replicates, count 16).
- The 1st sample was box-picked in the orchard, representing fruits handled with utmost care / minimal damage, of the lowest possible incidence of lenticel damage.
- The 2nd sample was taken at harvest, directly from crates or bins of fruits picked by the farm personnel, to establish the level of lenticel damage occurring subsequent to commercial harvest by farm pickers.
- The 3rd sample set was drawn upon arrival of the fruits at the packhouse, to verify the extent of damage manifesting during transport between orchard and packhouse.
- The 4th sample was taken directly from the packline, to ascertain the level of lenticel damage relating to the packing process.
- The samples were sent to Stellenbosch via refrigerated truck and stored in an ExperiCo cold room at 5.5 ºC for 25 days to simulate export.

Fruit ripening and evaluation:

- The fruits were ripened at 20 °C
- The evaluation comprised a full fruit quality examination, including the following physiological disorders (grey-pulp, black cold damage, lenticel damage, vascular browning, vascular staining) and pathological disorders (anthracnose and stem-end rot).

TRIAL 2: The effect of irrigation, applied in a high nitrogen orchard, on lenticel damage during storage of 'Hass' avocado – Objective 2

Site selection:

- A high nitrogen 'Hass' orchard in the Tzaneen area was selected for the trial purpose.

Treatments:

2 irrigation treatments were applied.

Treatment 1: Reduced irrigation

- Reducing the water supply by half in the last irrigation cycle, followed by stopping irrigation 5 weeks prior to harvest; applied to selected trees (5 tree replicates in total)
- No irrigation during the period of 5 weeks prior to harvest, by disconnecting the irrigation sprinklers; applied to selected trees (5 tree replicates in total)

Treatment 2: Full irrigation until harvest

The rest of the orchard was optimally irrigated, including a 5-day dry-out period prior to harvest to ensure that the soil moisture is within SAAGA harvest protocol (5 tree replicates in total).

Harvest and cold storage:

- Fruits were harvested for storage purposes 5 weeks after the no-irrigation treatment started.
- For each treatment 10 boxes Count 16 (160 fruits) sized fruits were harvested, taking care to minimise lenticel damage:
  - 5 Boxes was rolled in a 10 L bucket according the "Jostling method"
  - The remaining 5 boxes were not "Jostled", acting as an untreated control
- The samples were sent to Stellenbosch via refrigerated truck and stored at the ExperiCo facilities at 5.5 °C for 25 days to simulate export.

Fruit ripening and evaluation:

- The fruits were ripened at 20 °C and subsequently evaluated.
- The evaluation comprised a full fruit quality examination, including the following physiological disorders: grey-pulp, black cold damage, lenticel damage, vascular browning, vascular staining; and pathological disorders (anthracnose and stem-end rot).

TRIAL 3: The effect of late foliar nutrient sprays in a high nitrogen orchard, 3 months prior to harvest, on lenticel damage of 'Hass' avocado – Objective 3

Background to trial conducted

The nutritionally optimum orchard of Producer F in 2019 resulted in a high % sound fruits (70%) and therefore the least lenticel damage, furthermore exhibiting the highest fruit skin Ca, Mg and B values (0.18%, 0.18% and 107.6 mg/kg respectively). Similarly, the high nitrogen orchard (3rd least lenticel damage) of producer PH2A (2019) exhibited fruit skin Ca, Mg and B values of 0.16%, 0.157% and 116.4 mg/kg, respectively. Generally, increased lenticel damage occurred on fruits from high N orchards compared to optimum N in 2019. The need existed to determine if foliar sprays of Ca, Mg and B can reduce the sensitivity towards lenticel damage in high nitrogen orchards, furthermore if the Ca : N ratio can be improved and hence reduce lenticel damage.

It is known that chelated Ca, Mg and B are needed for cell wall development and fruit set and that boron encourages the *uptake and movement of cation nutrients* which includes Mg and Ca within the plant (Plich and Wojcik, 2008). In addition, mineral elements such as B and Ca are influential in the structural composition and in the assembly of the cell wall network by

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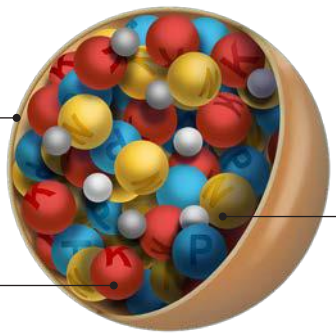

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cross-linking pectin polymers (Islam & Mele, 2018; Morris *et al*., 1982; Kobayshi, 1986). In addition, Ca and B may also interact with pectins which can assist in increased cell wall integrity. It is also hypothesized that silicon (Si) improves the absorption of B and hence improves absorption of Ca. Furthermore, firmness was improved at harvest and retained during storage of tomatoes treated by foliar application of Si and B, by cross-linking the pectin molecules (Weerahewa and David, 2015). Pear fruits treated with B were also shown to be firmer (Khalaj *et al*., 2017). The influence of Si, B and Ca applications in reducing lenticel damage of avocado needed to be verified by research.

Site selection:
One high nitrogen 'Hass' orchard in the Tzaneen area was selected for the 2020 trial purposes. The orchard used full sprinkler irrigation and 5 weeks prior to harvest, the sprinklers of all the trial treatment trees were disconnected, therefore the trees only received rain and no irrigation for 5 weeks prior to harvest.

Spray treatments:
Treatment 1:
- Untreated control

Treatment 2:
- Foliar application of boron and calcium in combination (no silicon)

Treatment 3:
- Foliar application of boron and calcium in combination, as well as a combination of silicon and boron
- The foliar applications comprised 3 sprays of boron + calcium (7 day intervals over a period of 21 days, with and without silicon sprays a day before and after the combination sprays)
- The foliar spray treatments consisted of 5 tree replicates and 5 tree replicates of untreated control.

The 5 sprays included the following:
- Spray 1: A combination spray of silicon only (Ecoksil: 164 g/kg K, 127 g/kg Si) and chelated boron (Flo-Bor: 50-150 mL / 100 mL)
- Sprays 2, 3 and 4: A combination sprays of chelated boron (Flo-Bor: 50-150 mL / 100 mL) and calcium (Calsimax: 500 mL / 100 L water)
- Spray 5: A combination spray of silicon (Ecoksil: 164 g/kg K, 127 g/kg Si) and chelated boron (Flo-Bor: 50-150 mL / 100 mL B.

Harvest and cold storage:
- Fruits were harvested for storage purposes 5 weeks after the no-irrigation treatment started.
- For each treatment 10 boxes count 16 (160 fruits) sized fruits were harvested with care to minimise lenticel damage:
  - 5 Boxes was rolled in a 10 L bucket according the "Jostling method"
  - The remaining 5 boxes was not "Jostled", acting as an untreated control
- The samples were sent to Stellenbosch via refrigerated truck and stored at the ExperiCo facilities at 5.5 °C for 25 days to simulate export.

Fruit ripening and evaluation:
- The fruits were ripened at 20 °C and subsequently evaluated.
- The evaluation comprised a full fruit quality examination, including the following physiological disorders: grey-pulp, black cold damage, lenticel damage, vascular browning, vascular staining; and pathological disorders (anthracnose and stem-end rot).

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

RESULTS AND DISCUSSION

TRIAL 1: To determine the influence of handling 'Hass' fruit in an orchard of high and optimum nitrogen levels on the occurrence of lenticel damage after storage, utilising different irrigation regimes (Objective 1)

Adherence to soil moisture protocol
The SAAGA protocol recommends "Avoid picking from orchards with soils at field capacity (tensiometer reading of 20-30 kPa, 500 mm deep, top soil containing most roots), 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 during 2019, one of the most important industry protocols as far as control of lenticel damage is concerned was not adhered to.

Producers either use tensiometers (kPa) or probes (mm) to measure soil moisture to plan and manage their irrigation cycles (Table 1):
- The 4 orchards of Producer I in 2020 made use of tensiometers. Two of these orchards ([2] PI S1B 2020 and [3] (PI 43B 2020) complied to the industry protocol with tensiometer readings of 40 kPa and 60 kPa respectively.
- However, with the 2 high nitrogen orchards of Producer I ([6] PI S3A 2020 and [7] PI S2A 2020) that was harvested at 32 kPa and 22 kPa, respectively, both obtained increased susceptibility to develop lenticel damage (Table 2).
  - The protocol indicates to dry out the soil higher than 30 kPa, as field capacity is obtained between 20-30 kPa. In the case of orchard [7] PI S2A 2020, with a soil moisture of 22 kPa, the orchard was too wet as it falls very close to the wetter than field capacity range (0-20 kPa) of tensiometer readings.
  - As the soil moisture reading of 32 kPa in the case of [6] PI S3A 2020 was still close to field capacity margin of 30 kPa and obtained a high incidence of lenticel damage, it is recommended to pick closer to the next irrigation as this will ensure that drying out of the soil is adequate.

The producer indicated that they usually irrigate these medium texture soils at soil moisture of 40 kPa.
- Literature indicates that for medium texture soils irrigation is required between 40 to 55 kPa to avoid damage that occurs at too dry soil moisture values of 60-80 kPa. Heavy clay soils on the other hand needs to be dried out further and irrigation is desirable as soil suction values reach 70-80 kPa.
- High nitrogen orchards that are harvested during the late season are still quite susceptible to develop lenticel damage that was also pointed out in 2019. Therefore it is important to use the soil moisture readings of orchards to be harvested as closely monitored measure to decide when to harvest.

- Producer F did not make use of probes or tensiometers in orchard [1] PF1 2019 and the last rain was 7 days before the harvest date and the dry-out period was adequate to safely say that the soil moisture was within protocol.
- The cumulative lenticel damage incidence of orchard H2 (Producer H 2019) that was visited and sampled twice during harvest when the probe soil moisture reading was too wet ([5] H2A 2019, -6 mm) and dry ([9] H2B 2019, +4 mm) (2019), differed by almost 40%, with the highest level exhibited for orchard [9] H2B 2019. This can be ascribed to the difference in soil moisture levels at harvest for the two sets of fruit samples. *Adherence to the industry soil moisture protocol resulted in much lower lenticel damage.* Furthermore, lenticel damage increased as the fruits of both soil moisture treatments were subjected to additional handling, however, more so for orchard [9] H2B 2019 that was harvested at too wet soil moisture.
  - To dry out the soil to +4 mm until the day before the next irrigation that took place at +5 mm in the case of medium texture soils is advisable.
  - However, in soil consisting of higher clay content that dries out slower, irrigation is needed between 10 to 16 days later that vary between +10 mm to +16 mm soil moisture. In a similar way it is advisable to dry out the soil until 1 day before the expected irrigation day, which entails the proper management of probe data that must be checked on a daily basis.
- The findings of adherence to or applying the stipulation to avoid harvesting at field capacity at orchard level by the 9 orchards, are summarised in Table 1.

Lenticel damage

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.

Two-way analysis of variance (ANOVA) was applied by analyzing the data in Statistica (statistical software) and using the LSD test ($\alpha = 0.05$) to compare treatment means (Table 2), for Factor A (9 orchards) and Factor B (4 sampling points). A significant interaction occurred between Factor A (orchard) and Factor B (sampling points).

<u>Comparison between different orchards, for each of the sampling points, between orchards</u>

- Sampling points A, B, C and D
  - A common result occurred for each of the 4 sampling points for the level of lenticel damage occurring between orchards. Significantly lower lenticel damage was recorded on fruits for 5 of the 9 producers / orchards ([1] F 2019, [2] IS1B 2020, [3] I43B 2020, [4] G1 2019, [5] H2A 2019) compared to fruits from the remaining producers / orchards ([6] IS3A 2020, [7] IS2A 2020, [8] G1 2020 and [9] H2A 2019).
    - These 5 orchards were harvested in adherence to soil moisture protocol.
    - In 3 of the 5 orchards exhibiting lower lenticel damage, optimum leaf N levels were present, with 2 of these 3 orchards exhibiting optimum leaf Ca, Mg and B levels ([1] F 2019 and [2] IS1B 2020).
  - The shared feature of the orchards exhibiting significant higher lenticel damage is the presence of high leaf N levels in all 4 orchards and low leaf B in 3 orchards, while 3 of the 4 orchards did not adhere to soil moisture protocol for harvesting ([6] IS3A 2020, [7] IS2A 2020, [8] G1 2020 and [9] H2B 2019).
  - Furthermore, fruits sampled directly after being box-picked (A) exhibited significantly lower lenticel damage for 2 producers / orchards ([1] F 2019 and [2] IS1B 2020) compared to 2 orchards ([4] G1 2019 and [5] H2A 2019). The common feature of the orchards exhibiting lower lenticel damage is the presence of optimum leaf N, Ca, Mg and B, opposed to high leaf N.

Discussion

- Only for one orchard [1] PF1 2020 of 9 orchards, no significant difference in incidence of lenticel damage occurred between the four sampling points, with the incidence varying very close to each other (between 30% - 32.5%), that differed significantly for the 8 orchards ([2] PI S1B 2020, [3] PI 43B 2020, [4] PG1 2019, [5] PH2A 2019, [6] PI S3A 2020, [7] PI S2A 2020, [8] PG1 2020, [9] PH2B 2019).
- *The finding implicates* that lenticel damage was not induced by additional steps in the handling chain for this producer and orchard.
  - Initially the five weeks of no irrigation prior to harvest was pointed out as the possible reason for the low incidence of lenticel damage, however, the reduced irrigation was replicated in a High Nitrogen orchard in an attempt to reduce the incidence of lenticel damage, and proved that it was not the case (see trial 2 discussion).
  - A nutritionally optimum orchard with optimum leaf N (1.3%), optimum leaf Ca (1.2%) and optimum leaf B (50 mg/kg) is more resistant towards developing lenticel damage.

Table 1: Harvesting practices followed at 9 orchards according to soil moisture parameters or harvesting schedules according to days allowed after rain

Orchard number	Producer code	Tensiometer reading (if used) kPa	Probe reading (if used) mm	Number of days allowed after last rain (days)	Other comments
1	F1 2019	(-)	(-)	7	Irrigation stops 5 weeks prior to picking due to shortage of water on the farm
2	I S1B 2020	72 kPa	(-)		Full irrigation
3	I 43B 2020	40 kPa	(-)		Drop line irrigation
4	G 1 2019	(-)	+10 mm		Full irrigation, sprinklers
5	H 2A 2019	(-)	+4 mm		Full irrigation, sprinklers
6	I S3A 2020	32 kPa	(-)		Full irrigation, sprinklers
7	I S2A 2020	20 kPa	(-)		Full irrigation, sprinklers
8	G1 2020	(-)	+10 mm		Full irrigation, sprinklers
9	H2B 2019	(-)	-6 mm		Full irrigation, sprinklers

Table 2: The incidence of lenticel damage on fruit of 9 '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 packhouse, and (d) from the pack-line, representing Two-way ANOVA for 9 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 pick-ers	(c) Upon arrival at pack-house	(d) packed on pack-line
1. PF1 2019	32.5a	30.0a	32.5a	30.0a	1. PF1 2019	31.3	48.33	55.6	65.6	71.8
2. PIS1B 2020	40b	40b	45bcd	47.5cde	2. PIS1B 2020	43.1				
3. PI43B 2020	41.3bc	47.5cde	48.75def	52.5efg	3. PI43B 2020	47.5				
4. PG1 2019	47.5cde	53.8efgh	61.3ijkl	66.3kl	4. PG1 2019	57.2				
5. PH2A 2019	47.5cde	51.3defgh	65.0kl	67.5l	5. PH2A 2019	57.8				
6. PIS3A 2020	57.5ghij	63.8jkl	85mn	92.5o	6. PIS3A 2020	73.8				
7. PIS2A 2020	55.0fghi	62.5jkl	83.8mn	93.8op	7. PIS2A 2020	73.8				
8. PG1 2020	53.8efgh	66.3kl	78.8m	96.3p	8. PG1 2020	74.7				
9. PH2B 2019	60.0hijkh	85.0mn	90.0no	100.0p	9. PH2B 2019	83.8				
P < 0.0000					**P < 0.0000**		**P < 0.0000**			

* Letter that are dissimilar are significantly based on the Fisher LSD (α = 0.05)

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- [2] PI S1B 2020 that is also a nutritionally optimum orchard with no significant differences in incidence of lenticel damage occurred between first two sampling points (box-picked) and with both sampling point values at 40% showing some resistance to develop lenticel damage. Upon arrival at the packhouse it increased to 45% and to 47% at the pack-line sampling point.
- Unfortunately this orchard had intermediate wind damage that explained the higher lenticel damage that was recorded that explained the 17.5% increase in lenticel damage when compared to [1] F1 2019 the quite resistant orchard when comparing pack-line values. In this regard in can be added that [1] PF1 2019 is a small orchard surrounded by big trees that provided 100% protection against wind damage.
- [1] PF1 2019 and [2] PSI S1B that were harvested in adherence to the industry soil moisture protocol, had significant less lenticel damage than recorded for the 2 High Nitrogen orchards that also complied to soil moisture protocol ([4] PG1 2019 and [5] PHB 2019) as well as the high incidence recorded for the four remaining High Nitrogen orchards ([6] PI S3A 2020, [7] PI S2A 2020, [8] PG1 2020, [9] PH2B 2019) with mostly non-compliance to industry soil moisture protocol.
  - This proves the sensitivity of High Nitrogen orchards towards developing lenticel damage.

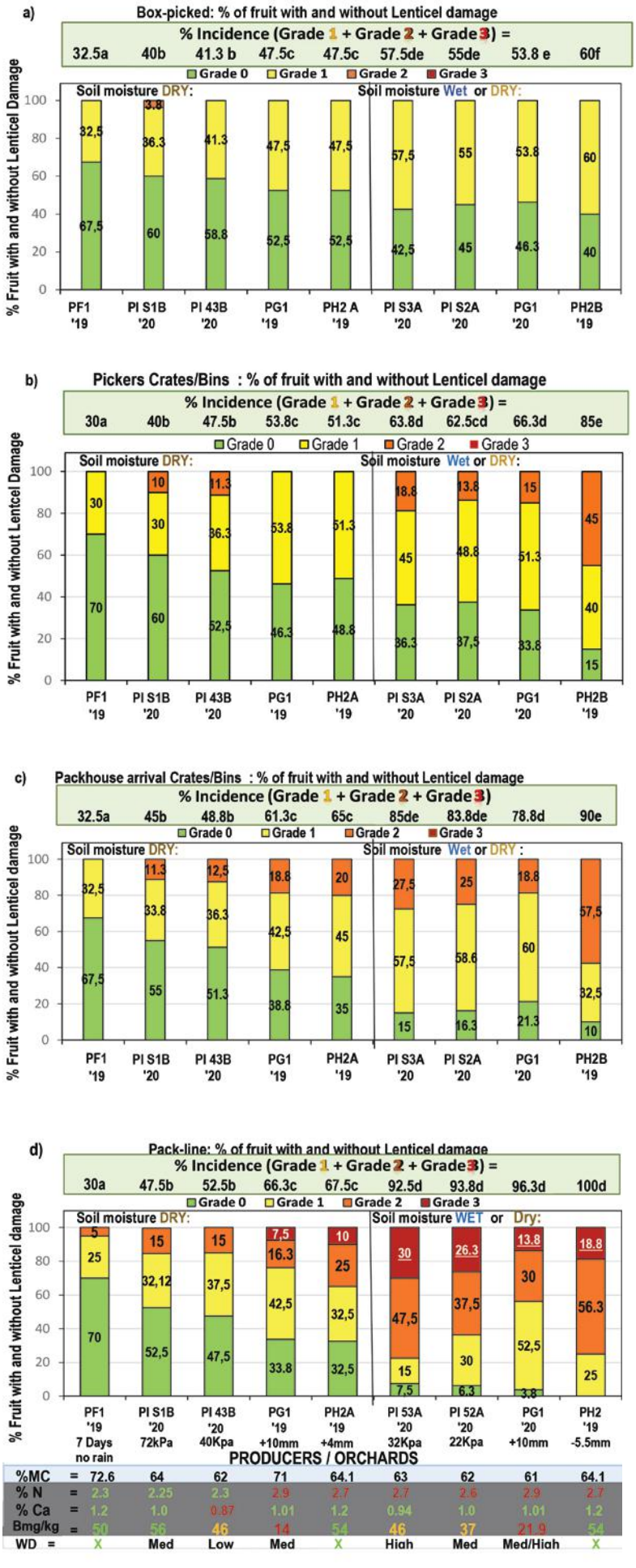
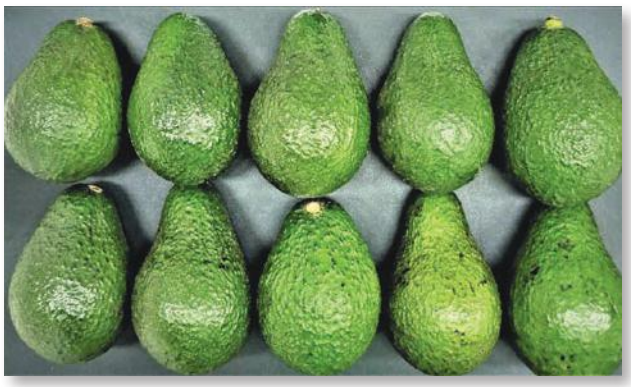
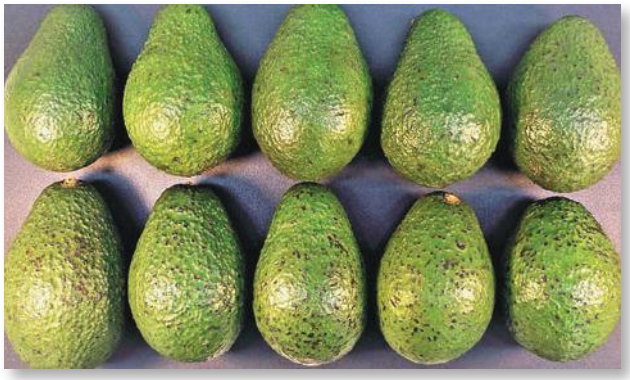


Figure 1: Percentage fruits with lenticel damage for samples procured from 9 'Hass' avocado orchards from (a) box-picked fruits, (b) picking teams harvest, (c) from the bins upon arrival at the packhouse, and (d) from the pack-line. The intensity of the disorder was quantified using PPECB's grading system (Grade 0, 1, 2 & 3). The producer code, soil moisture, leaf nutrient content (N, Ca and B), incidence of wind damage and sampling point is indicated. Stats: ANOVA; Fisher's LSD P<0.05.

a) Optimum N orchard: PI 43B 2020



b) Optimum N orchard: PI S1B 2020



c) High N orchard: PI S3A 2020

d) High N orchard: PI S2A 2020

e) High N orchard: PG 1 2020

f) High N orchard: PG 11 2020

g) Optimum N Orchard: PF1 11 2020

Figure 2: Visual appearance of class 1 export quality fruit (25 days cold storage) from different producers that were procured from the pack-line.

- PI, Orchards: a.)43B
  b.)S1B
  c.)S3A
  d.)S2A
- PG, Orchard 1: e.)2019
  f.)2020
- PF1, The optimum nitrogen orchard that stops irrigation 5 weeks prior to harvest.

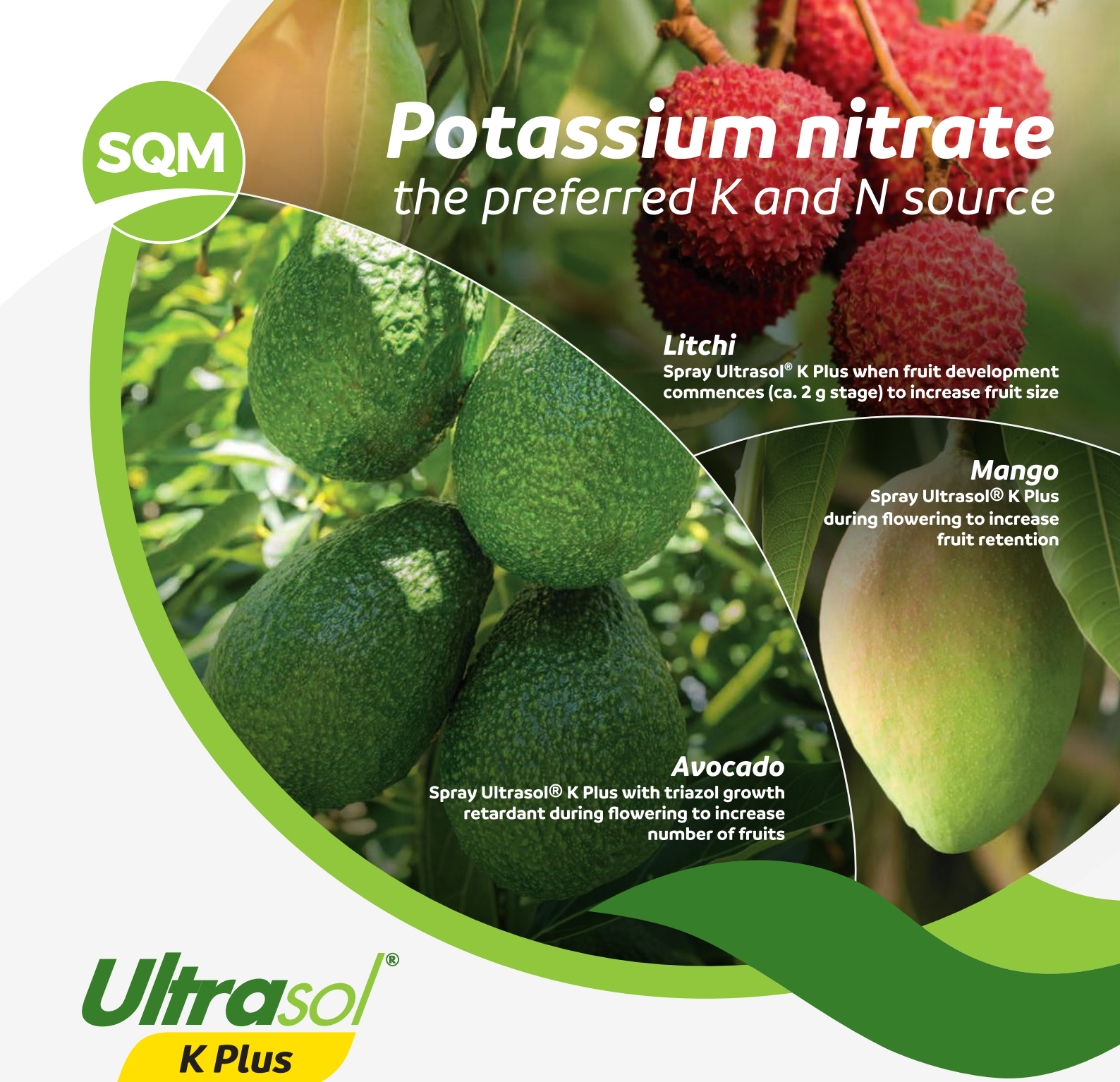
- [3] P34B 2020 had a low incidence of wind damage as a contributing factor for increased lenticel damage, as well low leaf Ca (0.87%) due to sub-optimal irrigation that limits the root uptake of Ca through transpiration, also added to increased sensitivity to lenticel damage because of fruit skin with limited integrity.
  - [3] P34B 2020 is an orchard with *dragline irrigation*. This sub-optimal irrigation provides roughly one third water volume during an irrigation cycle, compared to full sprinkler irrigation of the other orchards.
  - The reduced delivery of irrigation was further influenced by the very dry season with poor rainfall. In this regard it is known that limited transpiration during drought and limited water supply contribute to less Ca and B absorbed by the roots.
  - Besides the lower lenticel damage that was obtained by the optimum nitrogen orchards ([1] PF11 2019, [2] PI S1B 2020, [3] PI 43B 2020) when compared to High Nitrogen orchards, the lenticel damage lesions was less visible and smaller when compared to the High Nitrogen orchards (Fig. 2).
- Grade 3 damage, according to the PPECB lenticel grading protocol, only occurred on fruits that had passed over the pack-line, especially if harvested in orchards with *wet soil moisture*, as was also pointed out in 2019 (Fig. 1).
  - This emphasises the importance to adhere to the *industry soil moisture protocol*. In this regard, 3 orchards [6] PI S3A 2020, [7] PI S2A 2020, [9] PH2a 2019 with % grade 3 lenticel damage present ranged between 13.8% - 30%. Not adhering to the industry soil moisture protocol placed fruits from these orchards that were packed as Class 1 for export at risk of not passing the 10% maximum allowed by PPECB's grading system for Class 1 export fruit.
- Results of the same 'Hass' orchard ([5] PH2A 2019 and [9] PH2B 2019) (Fig. 1d) when harvesting fruits at "drier" soil moisture (probe reading +4 mm) one day before starting the next irrigation, provided fruits with much less lenticel damage compared to fruits harvested from the same orchard at a soil moisture content of -5.5 mm ([9] PH2B).
- The 2 High Nitrogen orchards ([4] PG1 2019 and [5] PHA, 2020) that were harvested at dry soil moisture obtained lenticel damage values of 66.4% and 67.5% respectively. The differences in lenticel damage between these High Nitrogen orchards and PF1's nutritionally optimum orchard with a low lenticel damage incidence of 30%, was 36.4% and 37.5% higher, respectively, showing the sensitivity of High Nitrogen orchards to developing lenticel damage.
  - *The findings implicated:*
    - That nutrition (N, Ca, Mg and B levels), as well as the irrigation regime may influence the level of postharvest lenticel damage of 'Hass' avocado.
    - Suboptimal irrigation may limit the root uptake of Ca and B through transpiration, and hence limit the integrity of fruit skin, adding to increased sensitivity to lenticel damage.
    - Sensitivity of High Nitrogen orchards towards developing lenticel damage is indicated.

<u>Comparison between sampling points for the different orchards</u>

- Sampling point A vs. D
  - Fruits sampled directly after being picked by an individual into boxes (Box picked = A) exhibited significantly lower lenticel damage compared to fruits picked by the farm and packed after subjection to the pack-line (Packed on pack-line = D), for 8 of the 9 orchards / producers [2] IS1B 2020, [3] I43B 2020, [4] G1 2019, [5] H2A 2019, [6] IS3A 2020, [7] IS2A 2020, [8] G1 2020 and [9] H2A 2019, equating to 88.9% of the orchards.
  - *The findings implicated:*
    - That exposing avocados to accumulative handling practices from picking by the farm labour force, travelling to the packhouse and subjecting the fruits to the pack-line, resulted in higher lenticel damage than avocados subjected to minimal handling by picking and packing directly into a box and no further handling thereafter.
    - That handling was the dominant factor influencing the level of lenticel damage and not nutrition (N, Ca, Mg and B levels) or the irrigation regime, since increased lenticel damage occurred on fruits sampled from most orchards (all except 1 orchard, [1] F1 2019, optimum nutrition and irrigation by sprinklers and period of drying prior to harvest).

- Sampling point A vs. C
  - Fruits sampled directly after being picked by an individual into boxes (Box picked = A) exhibited significantly lower lenticel damage compared to fruits picked by the farm and sampled upon arrival at packhouse (Packhouse arrival = C), for 7 of the 9 orchards / producers [3] I43B 2020, [4] G1 2019, [5] H2A 2019, [6] IS3A 2020, [7] IS2A 2020, [8] G1 2020 and [9] H2A 2019, equating to 77.8% of the orchards.
  - *The findings implicated:*
    - That similar to previous results, exposing avocados to accumulative handling practices from picking by the farm labour force, travelling to the packhouse and packing without subjecting the fruit to the pack-line, resulted in higher lenticel damage than avocados subjected to minimal handling by picking and packing directly into a box and no further handling thereafter.
    - That handling was the dominant factor influencing the level of lenticel damage and not nutrition (N, Ca, Mg and B levels) in combination with the irrigation regime, since

Potassium nitrate
the preferred K and N source



Litchi
Spray Ultrasol® K Plus when fruit development commences (ca. 2 g stage) to increase fruit size

Mango
Spray Ultrasol® K Plus during flowering to increase fruit retention

Avocado
Spray Ultrasol® K Plus with triazol growth retardant during flowering to increase number of fruits

Ultrasol® K Plus

Foliar fertilization is an important tool for the sustainable and productive management of crops:

- When soil conditions limit availability of soil applied nutrients;
- In conditions when high loss rates of soil applied nutrients may occur
- When the stage of plant growth, the internal demand and the environment conditions interact to limit a delivery of nutrients to critical plant organs
- When certain foliar applications are tested and proved to result in measurable and positive plant parameter responses.

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Contact details:
Mr. Duncan Napier: (082) 772 2207

E-mail: spn-emea@sqm.com

Registered by: SQM Africa (Pty) Ltd. / Act 36/1947: K5020 N= 130g/kg; P=0g/kg; K=380g/kg

sqmnutrition.com

Table 3: Rationale behind dividing 9 '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	Soil moisture at picking: Producers with probes(mm) or Tensiometers (kPa)	Days no rain	Comments / Other factors that played a role	Incidence of late wind damage	Leaf N (%)	Leaf Ca (%)	Leaf B (mg/kg)
Group A	Dry Soil Moisture	1. PF1 2019	-	7	No probes; **Irrigation stopped 1m**; rain thereafter, however **7d no rain prior to picking**; **optimum N and Ca ratio**; No wind damage	No	**2.30**	**1.20**	**50**
		2. I S1B 2020	72 kPa		Tensiometer; **Adherence to soil moisture protocol. Inhibited B Ploem transport to fruit pulp and skin Intermediate wind damage.**	Med	**2.25**	**1.00**	**56**
		3. I 43B 2020	40 kPa		Tensiometer; **Adherence to soil moisture protocol. Optimum N low Fruit Ca and B limited. Drop-line irrigation with limited water supply leads to low fruit pulp and skin B.** Low incidence of wind damage	Low	**2.3**	**0.87**	**46**
		4. PG1 2019	+10 mm	-	Probes; **Adherence to soil moisture protocol; High N,** though **optimum Ca, assisting with cell wall strength / properties;** Low incidence of wind damage	Low	**2.90**	**1.01**	**14**
		5. PH2A 2019	+4 mm	-	Probes; **Adherence to soil moisture protocol; Dry picking;** High N, **though optimum leaf and skin Ca and B; No wind damage**	No	**2.70**	**1.21**	**56**
Group B	Wet Soil Moisture or other factors that influenced the incidence of lenticel damage negatively	6. PI S3A 2020	32 kPa	-	Tensiometer; **No adherence to soil moisture protocol; Wet picking; High N,** though optimum Ca**; Intermediate incidence of wind damage**	High	**2.70**	**0.94**	**46**
		7. PI S2A 2020	22 kPa	-	Tensiometer; **No adherence to soil moisture protocol; Wet picking; High N,** though optimum Ca**; Intermediate incidence of wind damage**	Med	**2.60**	**1.00**	**37**
		8. PG1 2020	+10 mm	-	Probes; **Adherence to soil moisture protocol**; High N, **optimum leave Ca, assisting with cell wall strength**; **However, fruit skin B in skin was lower indication that Phloem translocation to the fruit was inhibited. Low incidence of wind damage**	Med/ high	**2.90**	**1.01**	**21.9**
		9. PH2B 2019	-6 mm	-	Probes; **No adherence to soil moisture protocol; Wet picking; High N, though optimum leaf and skin Ca and B; No wind damage**	No	**2.68**	**1.21**	**56**

Group A included orchards that were harvested within SAAGA soil moisture recommendations 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 high nitrogen and low calcium content, as well as the incidence of late wind damage

increased lenticel damage occurred in fruits sampled from most orchards (all except 2 orchards, [1] F 2019 and orchard [2] IS1B 2020).
    - That to some extent if N, Ca, Mg and B occur at optimal levels (orchard [1] F1 2019 and orchard [2] IS1B 2020), then the subjections of fruits to more radical handling practices is of lesser concern, not exacerbating the occurrence of lenticel damage.

- Sampling point A vs. B
  - Fruits sampled directly after being picked by an individual into boxes (Box picked = A) exhibited significantly lower lenticel damage compared to fruits sampled after being picked by the farm harvesting team and placed in lug boxes or bins (Farm picked = B), for 3 of the 9 orchards / producers [7] IS2A 2020, [8] G1 2020 and [9] H2A 2019, equating to 33.3% of the orchards.
  - *The findings implicated:*
    - That similar to previous results, exposing avocados to further handling practices, by adding travelling from the orchard to the packhouse after picking by the farm labour force, resulted in higher lenticel damage than avocados subjected to minimal handling by picking and packing directly into a box and no further handling thereafter.
    - Contrary to other comparisons, handling seemed not to be the dominant factor influencing the level of lenticel damage, but rather nutrition, since increased lenticel damage occurred in fruit sampled from less than 30% orchards (only [6] IS2A 2020, G1 2020 and H2B 2019), with all three the orchards of high N and optimum Ca and Mg, but low B.
    - Irrigation may have contributed to the exacerbation of lenticel damage, along with the nutrient imbalances, since increased damage occurred on fruits sprinkler irrigated, but not subjected to drying prior to harvest.

- Sampling point B vs. D
  - Fruits sampled after being picked by the farm harvesting team and placed in lug boxes or bins (Farm picked = B), exhibited significantly lower lenticel damage compared to fruits picked by the farm and packed after subjecting to the pack-line (Packed on pack-line = D), for 7 of the 9 orchards / producers [3] 43B 2020, [4] G1 2019, [5] H2A 2019, [6] IS3A 2020, [7] IS2A 2020, [8] G1 2020 and [9] H2B 2019, equating to 77.8% of the orchards.
  - *The findings implicated:*
    - That exposing avocados to accumulative handling practices from picking by the farm labour force, travelling to the packhouse and subjecting the fruits to the pack-line, resulted in higher lenticel damage than avocados subjected to only handling from picking and packing by farm labour.
    - Handling seemed to be the dominant factor influencing the level of lenticel damage and not leaf nutrition (N, Ca, Mg and B levels) or the irrigation regime, since increased lenticel damage occurred on fruits sampled from most orchards (all except 2 orchards, [1] PF11 2019 and [2] PI S1B 2020, optimum N, Mg, Ca and B nutrition and irrigation by sprinklers and acceptable period of drying prior to harvest).

- Sampling point B vs. C
  - Fruits sampled after being picked by the farm harvesting team and placed in lug boxes or bins (Farm picked = B), exhibited significantly lower lenticel damage compared to fruits picked by the farm and sampled upon arrival at the packhouse, including transport to the packhouse (Packhouse arrival = C), for 5 of the 9 orchards / producers [4] G1 2019, [5] H2A 2019, [6] IS3A 2020, [7] IS2A 2020 and [8] G1 2020, equating to 55.6% of the orchards.
  - *The findings implicated:*
    - That exposing avocados to accumulative handling practices from picking by the farm labour force, including travelling to the packhouse, resulted in higher lenticel damage than avocados subjected to only handling from picking and packing by farm labour.
    - Handling seemed to be the dominant factor influencing the level of lenticel damage and not nutrition (N, Ca, Mg and B levels) or the irrigation regime, since increased lenticel damage occurred on fruits sampled from most orchards (all except 4 orchards).

- Sampling point C vs. D
  - Fruits picked by the farm and sampled upon arrival at the packhouse (Packhouse arrival = C), exhibited significantly lower lenticel damage compared to fruits picked by the farm and packed after subjection to the pack-line (Packed on pack-line = D), for 4 of the 9 orchards / producers [6] IS3A 2020, [7] IS2A 2020, [8] G1 2020 and [9] H2B 2019, equating to 44.4% of the orchards.
    - Contrary to other comparisons, handling seemed not to be the dominant factor influencing the level of lenticel damage, but rather nutrition, since increased lenticel damage occurred on fruits sampled from less than 50% orchards (only IS3A 2020, IS2A 2020, G1 2020 and H2A 2019), with three of the orchards (IS3A 2020, IS2A 2020, G1 2020) of high N and optimum Ca and Mg, but low B.

Analysis of data subsequent to the primary analysis

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), attained fruits by the 1st 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 3).

Subsequent to the 1st analysis, data were subjected to the following analyses:

(i) Two-way ANOVA of 9 orchards, for comparison between the sampling points "A = box picked" and "B = farm picked" (Table 4)

(ii) Two-way ANOVA of 9 orchards, for comparison between the sampling points "A = box picked" and "C = packed upon arrival at packhouse" (Table 4)

(iii) Two-way ANOVA of 9 orchards, for comparison between the sampling points "A = box picked" and "D = packed on the pack-line" (Table 5)

(iv) Two-way ANOVA of 9 orchards, for comparison

Table 4: Incidence of lenticel damage on fruit of 9 'Hass' orchards, sampled at 2 points; (a) after personalised box pick and pack and (b) in the orchard from bins after farm picked, as well as (a) after personalised box pick and pack, and (c) upon arrival at the packhouse, presenting Two-way ANOVA results

	QUALITY PARAMETER – LENTICEL DAMAGE							
	Factor A (Orchard) x Factor B (Sampling points)			Factor A (Orchards)		Factor B (Sampling points)	
Group A	Orchard	a) After box pick	b) After farm pick			a) After box pick	b) After farm pick
Group A	1. PF1 2019	32.5a	30.0a	1. PF1 2019	31.3	48.3	55.6
	2. PI S1B 2020	40b	40b	2. PI S1B 2020	40.0		
	3. PI 43B 2020	41.3bc	47.5cd	3. PI 43B 2020	44.4		
	4. PG1 2019	47.5cd	53.8def	4. PG1 2019	49.4		
	5. PH2A 2019	47.5cd	51.3def	5. PH2A 2019	50.6		
Group B	6. PI S3A 2020	57.5efg	63.8gh	6. PI S3A 2020	58.8		
	7. PI S 2A 2020	55.0ef	62.5gh	7. PI S2A 2020	60.0		
	8. PG 1 2020	53.8def	66.3h	8. PG 1 2020	60.6		
	9. PH2B 2019	60.0fgh	85.0i	9. PH2B 2019	72.5		
	P<0.0000			P<0.0000		P<0.0000	

	QUALITY PARAMETER – LENTICEL DAMAGE						
	Factor A (Orchard) x Factor B (Sampling points)			Factor A (Orchards)		Factor B (Sampling points)	
Group	Orchard	a) After box pick	c) Upon arrival at packhouse			a) After box pick	c) Upon arrival at packhouse
Group A	1. PF1 2019	32.5a	32.5a	1. PF1 2019	32.5	48.3	65.6
	2. PI S1B 2020	40b	45.0bcd	2. PI S1B 2020	42.5		
	3. PI 43B 2020	41.3bc	48.8def	3. PI 43B 2020	45.0		
	4. PG1 2019	47.5cde	61.3hi	4. PG1 2019	54.4		
	5. PH2A 2019	47.5cde	65.0i	5. PH2A 2019	56.3		
Group B	6. PI S3A 2020	57.5gh	85.0jk	6. PI S3A 2020	66.3		
	7. PI S2A 2020	55.0fgh	83.8jk	7. PI S2A 2020	69.4		
	8. PG 1 2020	53.8efg	78.8j	8. PG 1 2020	71.3		
	9. PH2B 2019	60.0ghi	90.0l	9. PH2B 2019	75.0		
	P<0.0000			P<0.0000		P<0.0000	

* Different letters indicate statistically significant differences based on Fisher's LSD test (α = 0.05)

between the sampling points "B = farm picked" and "C = downloaded upon arrival at packhouse" (Table 5)

(vi) Two-way ANOVA of 9 orchards, for comparison between the sampling points "B = farm picked" and "D = packed on the pack-line" (Table 6)

(vii) Two-way ANOVA of 9 orchards, for comparison between the sampling points "C = downloaded upon arrival at the packhouse" and "D = packed on the pack-line" (Table 6).

Discussion

Two-way ANOVA for the 9 orchards indicated a significant interaction for each of the 6 comparisons between different sampling points (two-at-a-time, as shown in the layout for statistical analysis above):

"A = box picked" vs. "B = farm picked" (Table 4)

"A = box picked" vs. "C = farm picked and travel to the packhouse" (Table 4)

"A = box picked" vs. "D = farm picked, travel to the packhouse and subjected to the pack-line" (Table 5)

"B = box picked" vs. "C = farm picked and travel to the packhouse" (Table 5)

"B = box picked" vs. "D = farm picked, travel to the packhouse and subjected to the pack-line" (Table 6)

"C = farm picked and travel to the packhouse"

Table 5: Incidence of lenticel damage on fruit of 9 'Hass' orchards, sampled at 2 points; (a) after personalised box pick and packed, and (d) from the pack-line and (b) in the orchard from bins after farm picked, and (c) upon arrival at the packhouse, presenting Two-way ANOVA on 9 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)	
Group	Orchard	a) After box pick	d) From pack-line			a) After box pick	d) From pack-line
Group A	1. PF1 2019	32.5a	30.0a	1. PF1 2019	31.3	48.33	71.8
	2. PI S1B 2020	40b	47.5cd	2. PI S1B 2020	43.8		
	3. PI 43B 2020	41.3bc	52.5def	3. PI 43B 2020	46.9		
	4. PG1 2019	47.5cd	66.3gh	4. PG1 2019	56.88		
	5. PH2A 2019	47.5cd	67.5h	5. PH2A 2019	57.5		
Group B	6. PI S3A 2020	57.5efg	92.5i	6. PI S3A 2020	74.4		
	7. PI S 2A 2020	55.0ef	93.8ij	7. PI S2A 2020	75.0		
	8. PG 1 2020	53.8def	96.3ij	8. PG 1 2020	75.0		
	9. PH2B 2019	60.0fgh	100.0j	9. PH2B 2019	80.0		
	P<0.0000			P<0.0000		P<0.0000	

	QUALITY PARAMETER – LENTICEL DAMAGE						
	Factor A (Orchard) x Factor B (Sampling points)			Factor A (Orchards)		Factor B (Sampling points)	
Group	Orchard	b) After farm pick	c) Upon arrival at pack-house			b) After farm pick	c) Upon arrival at pack-house
Group A	1. PF1 2019	30.0a	32.5a	1. PF1 2019	31.3	55.6	65.6
	2. PI S1B 2020	40.0bc	45.0cd	2. PI S1B 2020	42.5		
	3. PI 43B 2020	47.5cde	48.75de	3. PI 43B 2020	48.1		
	4. PG1 2019	43.8ef	61.3fg	4. PG1 2019	57.5		
	5. PH2A 2019	51.3de	65.0g	5. PH2A 2019	58.13		
Group B	6. PI S3A 2020	63.8g	85.0hi	6. PI S3A 2020	72.5		
	7. PI S2A 2020	62.5g	83.8hi	7. PI S2A 2020	72.1		
	8. PG 1 2020	66.3g	78.8h	8. PG 1 2020	74.4		
	9. PH2B 2019	85.0hi	90.0i	9. PH2B 2019	87.5		
	P<0.0007			P<0.0000		P<0.0000	

* Different letters indicate statistically significant differences based on Fisher's LSD test

vs. "D = farm picked, travel to the packhouse and subjected to the pack-line" (Table 6).

A common result occurred across the 9 orchards for comparing handling practices to another (6 comparisons)

- Higher lenticel damage occurred on avocados with addition of handling practices to the previous e.g. farm picked fruit > lenticel damage compared to box picked fruit, farm picked and travel to the packhouse > lenticel damage compared to farm picked fruit and packing directly into boxes, farm picked, travel to the packhouse and subjected to the pack-line > lenticel damage compared to farm picked and travel to the packhouse.
- The occurrence of higher lenticel levels was most prominent for comparing packed avocados comprising more handling to less or minimal handling. D = farm picked, travel to the packhouse and subjected to the pack-line exhibited higher lenticel damage than fruit subjected to minimal handling (A = box picked) for 8 of the 9 orchards (equating to 88.9%) (Table 5), whereas if practice C = farm picked and travel to the packhouse is compared to practice A (C comprising one less step than D) then higher lenticel damage occurred for 8 of the

Table 6: Incidence of lenticel damage on fruit of 9 'Hass' orchards, sampled at 2 points; (b) in the orchard from bins after farm picked, and (d) from the pack-line, as well as c) upon arrival at the packhouse, and (d) from the pack-line, presenting Two-way ANOVA results

	QUALITY PARAMETER – LENTICEL DAMAGE							
	Factor A (Orchard) x Factor B (Sampling points)			Factor A (Orchards)			Factor B (Sampling points)	
Group	Orchard	a) After farm pick	b) From pack-line				a) After farm pick	b) From pack-line
Group A	1. PF1 2019	30.0a	30.0a	1.	PF1 2019	30	55.6	71.8
	2. PI S1B 2020	40.0b	47.5bc	2.	PI S1B 2020	43.8		
	3. PI 43B 2020	47.5bc	52.5c	3.	PI 43B 2020	50.0		
	4. PG1 2019	53.8c	66.3d	4.	PG1 2019	60.0		
	5. PH2A 2019	51.3c	67.5d	5.	PH2A 2019	59.4		
Group B	6. PI S3A 2020	63.8d	92.5ef	6.	PI S3A 2020	78.1		
	7. PI S 2A 2020	62.5d	93.8f	7.	PI S2A 2020	78.1		
	8. PG 1 2020	66.3d	96.3f	8.	PG 1 2020	81.3		
	9. PH2B 2019	85.0e	100.0f	9.	PH2B 2019	92.5		
	P<0.0000			P<0.0000			P<0.0000	

	QUALITY PARAMETER – LENTICEL DAMAGE							
	Factor A (Orchard) x Factor B (Sampling points)			Factor A (Orchards)			Factor B (Sampling points)	
Group	Orchard	c) Upon arrival at pack-house	d) From pack-line				c) Upon arrival at pack-house	d) From pack-line
Group A	1. PF1 2019	32.5a	30.0a	1.	PF1 2019	31.3	65.6	71.8
	2. PI S1B 2020	45.0b	47.5b	2.	PI S1B 2020	46.3		
	3. PI 43B 2020	48.8b	52.5b	3.	PI 43B 2020	50.6		
	4. PG1 2019	63.1c	66.3c	4.	PG1 2019	63.8		
	5. PH2A 2019	65.0c	67.5c	5.	PH2A 2019	66.3		
Group B	6. PI S3A 2020	85.0def	92.5fgh	6.	PI S3A 2020	87.5		
	7. PI S2A 2020	83.8de	93.8gh	7.	PI S2A 2020	88.8		
	8. PG 1 2020	78.8d	96.3gh	8.	PG 1 2020	88.8		
	9. PH2B 2019	90.0efg	100.0h	9.	PH2B 2019	95.0		
	P<0.0276			P<0.0000			P<0.0000	

* Different letters indicate statistically significant differences based on Fisher's LSD test (α = 0.05)

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9 orchards (equating to 77.8%) (Table 4), while practice B = farm picked is compared to practice A (B comprising two less handling steps than D, or one step more than A), then higher lenticel damage occurred for only 3 of the 9 orchards (equating to 33.3%) (Table 4).

- Similarly, when comparing B to D, more orchards exhibited higher lenticel damage than by comparing B to C (6 of the 9 orchards for B vs. D [Table 6] and 5 of the 9 orchards for B vs. C [Table 5], equating to 66.7 and 55.6%, respectively), due to more handling steps between B and D than between B and C.
  - *The findings implicated:*
    - The more practices involved in harvesting and packing of avocado (e.g. D vs. E, 4 vs 1 practices respectively), the higher the likelihood for the occurrence of lenticel damage on fruit of a greater number / percentage of orchards, with nutrition not influencing the levels of lenticel damage to a major extent.
    - In contrast, with less differences in the number of practices (e.g. D vs. C and B vs. A, 2x vs. 1x practice for both comparisons), the lower the likelihood that the occurrence of lenticel damage on fruit is related to a high number of orchards, with nutrition more dominant in influencing the level of lenticel damage. This scenario was applicable for only 3 orchards ([6] IS3A 2020, [7] IS2A 2020 and [8] G1 2020), all of which showed high leaf N levels and low leaf B.
    - Handling seemed to be the dominant factor influencing the level of lenticel damage and not nutrition (leaf N, Ca, Mg and B levels) or the irrigation regime, since increased lenticel damage occurred in fruit sampled from most orchards (all except 2 orchards, [1] F 2019, optimum nutrition and irrigation by sprinklers and period of drying prior to harvest and [3] I43B 2020, optimum leaf N and Mg, but lower Ca and B).

A common result occurred for comparing each of the 9 orchards for the individual handling practices (A, B, C and D)

- Higher lenticel damage occurred on avocado for each of the four handling practices (A, B, C and D), for 4 orchards [6] IS3A 2020, [7] IS2A 2020, [8] G1 2020 and [9] H2A 2019, compared to lower levels of lenticel damage on the remaining 5 orchards [1] F 2019, [2] IS1B 2020, [3] I43B 2020, [4] G1 2019, [5] H2A 2019.
- Furthermore, lenticel damage was lower on fruit of orchards [1] F 2019 and [2] IS1B 2020, compared to orchards [4] G1 2019 and [5] H2A 2019, for sampling points / handling practices A, B, C and D, and lower on fruit from orchard / producer [1] F 2019 compared to [2] IS1B 2020 and [3] I43B 2020.
  - *The findings implicated:*
    - When comparing individual orchards for a specific handling practice, whether comprising minimal handling (A) or extensive handling (D), the higher the likelihood for the occurrence of lenticel damage on fruits from nutrition sub-optimal orchards. Higher lenticel damage occurred on avocado for each of the four handling practices (A, B, C and D) for 3 orchards [6] IS3A 2020, [7] IS2A 2020 and [8] G1 2020, all of high leaf N and low leaf B, compared to lower levels of lenticel damage on the 3 orchards [1] F 2019, [2] IS1B 2020, [5] H2A 2019, all of optimal leaf N, Ca, Mg and B.
    - In contrast, with less differences in the number of practices (e.g. D vs. C and B vs. A, 2 vs. 1 practices for both comparisons), the lower the likelihood that the occurrence of lenticel damage on fruit is related to a high number of orchards, with nutrition more dominant in influencing the level of lenticel damage. This scenario was applicable for 3 orchards ([6] IS3A 2020, [7] IS2A 2020, [8] G1 2020), all of which showed high N levels and low B.
    - That exposing avocados to accumulative handling practices from picking by the farm labour force, travelling to the packhouse and subjecting the fruit to the pack-line, resulted in higher lenticel damage than avocados subjected to only handling from picking and packing by farm labour.
    - Handling seemed to be the dominant factor influencing the level of lenticel damage and not nutrition (N, Ca, Mg and B levels) or the irrigation regime, since increased lenticel damage occurred in fruit sampled from most orchards (all except 2 orchards, F 2019, optimum nutrition and irrigation by sprinklers and period of drying prior to harvest and I43B 2020, optimum N and Mg, but lower Ca and B).

Leaf, fruit skin and fruit pulp nutrient content in relation to lenticel damage (Table 7)

It is known that Ca provides improved cell wall integrity and hence lenticel damage (Polevoiy, 1989). Furthermore, that chelated Ca, Mg and B are needed for cell wall development and fruit set and that B encourages the uptake and movement of cation nutrients such as Mg and Ca within the plant (Plich and Wojcik, 2008). Taking this into account, leaf nutrient content (sampled in May each year), as well as fruit pulp and skin samples (taken at harvest of fruit sampled at each orchard for Ca, Mg and B nutrient content), were used as parameters of potential differences in sensitivity to develop lenticel damage. Orchards were identified according to their difference in N content, as the 2019 results indicated that high N orchards were more sensitive than optimum N orchards in developing lenticel damage.

To enable the interpretation of leaf, fruit, pulp and fruit skin nutrient results, knowledge of nutrient absorption by the roots and transportation is needed. Increasing Ca concentration in fruit by increasing soil applications has often been inconsistent, primarily

Table 7: Leaf, fruit pulp and fruit skin nutrient values, including nitrogen (N), calcium (Ca), magnesium (Mg) and boron (B) of 9 orchards

Leaf, pulp and skin nutrient values														
			N %			Ca %			Mg %			B mg/kg		
Orchard		Lenticel damage %	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	PF11 2019	30.0	2.30	0.45	0.76	1.20	0.10	0.18	0.50	0.14	0.18	50.0	82.4	107.6
	PI S1B 2020	47.5	2.25	0.56	0.70	1.10	0.09	0.17	0.55	0.11	0.13	56.0	67.0	62.0
	PI 43B 2020	52.5	2.30	0.48	0.78	0.87	0.08	0.13	0.52	0.12	0.14	46.0	52.0	48.0
	PG1 2019	66.3	2.90	0.76	0.93	1.01	0.09	0.17	0.41	0.13	0.17	14.0	37.9	35.3
	PH2A 2019	67.5	2.68	0.49	0.95	1.21	0.10	0.16	0.60	0.12	0.16	54.0	99.0	116.4
Dry or Wet Moisture + Other factors	PI S3A 2020	92.5	2.55	0.89	1.21	1.0	0.08	0.16	0.55	0.13	0.13	46.0	60.0	61.0
	PI S2A 2020	93.8	2.70	0.86	1.11	0.95	0.07	0.17	0.56	0.13	0.13	37.0	76.0	52.1
	PG1 2020	96.3	2.90	0.86	0.98	1.01	0.07	0.13	0.41	0.11	0.14	21.9	42.0	44.0
	PH2B 2019	100.0	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 8: Incidence of anthracnose and stem-end rot of 'Hass' avocado fruit of 9 orchards for the difference between box-picked at harvest and fruits sampled from the pack-line in 2019 and 2020

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. PF1 2019	5	5.0	1.	PF1 2019	5.0c	3.06	4.72
2. PI S1B 2020	1.3	1.3	2.	PI S1B 2020	1.3ab		
3. PI 43B 2020	3.8	8.8	3.	PI 43B 2020	6.3c		
4. PG1 2019	5.0	3.8	4.	PG1 2019	4.4bc		
5. PH2A 2019	5.0	3.8	5.	PH2A 2019	7.5c		
6. PI S3A 2020	1.3	1.3	6.	PI S3A 2020	1.3ab		
7. PI S2A 2020	1.1	8.8	7.	PI S2A 2020	5.0c		
8. PG 1 2020	0.0	0.0	8.	PG 1 2020	0.0a		
9. PH2B 2019	3.5	10.0	9.	PH2B 2019	4.4bc		
	P < 0.1528			P < 0.0001		P < 0.0586	

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	Packhouse
1. PF1 2019	0.0	5.0	1.	PF1 2019	2.5b	2.08	2.78
2. PI S1B 2020	0.0	0.0	2.	PI S1B 2020	0.0a		
3. PI 43B 2020	0.0	0.0	3.	PI 43B 2020	0.0a		
4. PG1 2019	7.5	10.0	4.	PG1 2019	8.8d		
5. PH2A 2019	3.8	5.0	5.	PH2A 2019	4.4bc		
6. PI S3A 2020	0.0	0.0	6.	PI S3A 2020	0.0a		
7. PI S2A 2020	0.0	0.0	7.	PI S2A 2020	0.0a		
8. PG 1 2020	0.0	0.0	8.	PG 1 2020	0.0a		
9. PH2B 2019	6.3	6.3	9.	PH2B 2019	6.3c		
	P < 0.962			P < 0.0000		P < 0.2153	

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

due to the relatively immobility of Ca in the soil and plant and its dependence on water for distribution into plant tissue with transpiration (Lahav and Whiley, 2002). Transpiration is the main driving force for the xylem stream (White and Broadley, 2003) in which Ca seems to move relatively freely, while this ion is also well known to be substantially immobile in the phloem (Buckowak and Wittwer, 1957). Along with the observation that fruit are largely phloem fed, Ca's well known xylem mobility and phloem immobility explain in part why fruit are generally low-Ca organs and also why higher fruit transpiration rates are occasionally associated with increased fruit Ca levels (Cline and Hanson, 1992; Tromp and Van Vuure, 1993; Montanaro *et al.*, 2006 and 2010). Because Ca moves passively, it tends to concentrate in those tissues that lose more water. Therefore, leaves tend to accumulate more Ca *at the expense of developing fruit*. The latter author indicated that Ca absorption and regulation into fruit requires a holistic approach which should consider rootstock, soil type, water availability to the roots, and the potential for excess vegetative vigour (which can be promoted by N fertilisation) to compete with Ca accumulation in the fruit.

Calcium reached a maximum concentration within fruit 7 weeks after fruit set, declining rapidly until 16 weeks after fruit set, remaining fairly stable until picking. Avocado fruit only have stomata during the first 7 weeks of fruit development where after it is converted to lenticels, that limits optimum xylem transport of Ca and B because of the reduced transpiration stream. Concentration differences due to irrigation regimes were only evident between 7 and 16 weeks after set. Irrigation at a soil moisture tension of 55 kPa resulted in the highest Ca concentration, while very frequent (replenishment at 35 kPa soil moisture tension) and occasional (replenishment at 80 kPa) irrigation were lower, particularly the latter which showed the most rapid decline (Bower, 1985). It was indicated that any influence of Ca concentration on fruit quality seems to occur early in fruit development, and it is suggested that optimal irrigation be practised at this time to ensure the maximum Ca absorption into fruit.

Plants take up B via the roots, predominantly in the form of boric acid. It is a small, soluble, undissociated and uncharged molecule, which easily migrates across the lipid bilayers. Boron is the *only* element which is not taken up from the soil as an ion. Boron is transported by passive diffusion and without protein catalysis and energy consumption. Because of the cell's high permeability to B, characteristic patterns of flux along the transpiration stream via xylem, and accumulation in the tips of the leaves, passive diffusion was long considered as the only mechanism of transport (Nable, 1988; Raven, 1980). Phloem mobility of B was demonstrated in avocado fruit, proving the translocation from mature leaves into inflorescences, new leaves and developing fruit (Minchin *et al*., 2012), concluding that B is phloem mobile in avocado and that the ability for B transport will depend upon the amount of Perseitol (a C7 sugar) in the phloem sap.

Discussion

The results of leaf and fruit pulp and N, Ca, Mg and B nutrient content of the current trial indicated several observations that could link to differences in lenticel damage (Table 7):

- Orchard [1] PF1 2019, with optimum leaf N (2.3%), optimum Ca (1.2%), optimum Mg (0.5%) and optimum B (50 mg/kg), harvested in adherence with soil moisture protocol, exhibited the lowest lenticel damage of 30%:
  - This orchard obtained the highest fruit skin Ca content (0.18%). The producer irrigated the orchard optimally on a weekly basis from flowering until 5 weeks prior to harvest. He reduced the volume of water in half, not to stress the plants after no irrigation was applied during the following 5 weeks.
  - The lower fruit Ca content values compared to the high leaf Ca content value confirms the literature, that Ca is only transported to the fruit via xylem with the transpiration stream as driving force.
  - It is known that Ca provides improved cell wall integrity (Polevoiy, 1989) and protection against lenticel damage.
  - The fruit pulp and skin B values were much higher (82.4 and 107 mg/kg respectively) compared to in the leaf optimum B value (50 mg/kg). This confirms that B is also transported via leaves through phloem transport to the developing fruit.
    - As the skin B content was increased to its maximum compared to the other orchards (± 100% increase), this indicates there was no limiting factor to minimise phloem transport of B from the leaves to the fruit.
  - This orchard also obtained the highest fruit skin Mg value of 0.18%.
  - As Mg, Ca, and B is related to cell wall integrity, it can be assumed that high values of these three nutrients in the fruit skin of this orchard, contributed towards its resistance to lenticel damage.
- Orchard [2] PI S1B 2020 with optimum leaf N (2.25%), optimum Ca (1.1%), optimum Mg (0.55%) and optimum B (56 mg/kg), was similar to [1] PF11 2019, however, this orchard exhibited a significant higher level of lenticel damage (47.5%) compared to [1] PF11 2019 (17% higher). Attributing factors that could have increased the sensitivity towards lenticel damage include:
  - Orchard [2] PI SI B 2020 obtained an intermediate incidence of wind damage that masked the positive protective effect of high skin Ca and skin B on lenticel damage.
  - However, in contrast to the nutritionally optimum orchard [1] PF1 2019, fruit pulp and skin B values (67 and 62 mg/kg respectively) were not increased to the same extent compared to the leaf optimum B value (56 mg/kg). In this orchard the skin B value increased with ± 6%, compared to the ± 100% increase of orchard [1] PF112019.

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- This indicates that B was not effectively transported via leaves through phloem transport to the developing fruits. This indicates that a stress factor was present that led to reduced photosynthetic output that limited the amount of Perseitol 9 (a C7 sugar) that is needed for phloem transport of B from the leaves to the fruit.
- Phloem translocation was not as effective as for [1] PF11 2019, that possibly led to reduced cell wall integrity that could have contributed as an additional factor to explain the higher lenticel damage obtained. Although the reason is unknown, the amount of Perseitol that carries B was less in this orchard.
- This orchard obtained high fruit skin Ca content (0.17%) that was comparable to orchard PF11 2019. This indicates that the transpiration stream was optimally sustained with optimum irrigation during the first 6-7 weeks of fruit development.

• In a high nitrogen orchard, [5] H2a 2019, with leaf Ca and B content (1.2% and 54 mg/kg respectively) similar to the optimum N orchard [1] PF11 2019, the fruit pulp and skin B (99 and 116.4 mg/kg) also increased in a similar manner as was the case for orchard [1] PF11 2019.
  - It is known that high N inhibits the absorption of Ca and B in soils, therefore higher dosages or more soil applications of B and Ca need to be applied, which was clearly effectively been conducted in this orchard.
  - However, high N orchards need increased Ca content to keep the (N : Ca) ratio comparable to optimum N orchards. High N is linked to increased cell division and growth. Fruits of high N orchards usually have bigger cells with thinner cell walls, therefore more skin Ca and B is needed to ensure maximum cell wall integrity in order to reduce the sensitivity of high N orchards towards lenticel damage.
  - During the 2 years of the project only three orchards showed this trend of increased skin boron (± 100% increase of the leaf B value). The need exists to verify why the photosynthetic outputs are inhibited in most of the orchards. Preliminarily it can be pointed out that optimum irrigation was applied by producer H ([5] PH2A and [9] PH2B) on a weekly basis throughout the season. Two groups of 'Hass' are irrigated either on Thursdays or Fridays. Water stress was never a factor. During water stress the soil moisture is dried out further than the +5 mm when the producer usually irrigates. Stomatal closure during too dry soil moisture inhibits in the long run photosynthesis, as optimum gas exchange is needed through open stomata to ensure optimum photosynthetic output.
  - When the same orchard was picked at soil moisture of -5 mm, lenticel damage increased to 100%, indicating that wet soil moisture masks the positive effect of higher fruit skin Ca and B.

The findings implicated:

• Optimum leaf B, Ca and Mg values of an optimum N orchard can be indicative of resistance to develop lenticel damage, but the extent to which these nutrients accumulate in the fruit is influenced by different actions:
  - Fruit B and Ca is dependent on an optimum transpiration stream that can only be obtained with optimum irrigation during the first 6 weeks of fruit development. In the case of Ca that is only transported via the transpiration stream this is very important to ensure optimum cell wall integrity.
  - In the case of B which is also transported through the phloem from older leaves during fruit development that influence the amount of B that accumulate in the fruit skin.
  - An orchard with optimum leaf N, Ca, Mg and B was able to accumulate B in the fruit skin with a value that was ± 100% higher than the leaf B value obtained the least lenticel damage. Currently the literature points out that there is an increase in the fruit pulp B but no study investigates the effect on fruit skin values.
  - Another orchard with very similar optimum leaf N, Ca, Mg and B composition could not attain the same increase in fruit skin B (only a 6% increase), but only obtained a higher incidence of lenticel damage.
  - This lower fruit skin B content obtained (although the leaf B was at its optimum), implicates that photosynthetic output was inhibited during fruit development that led to less Perseitol available to act as carrier, which influenced the effective and optimum phloem transport of B to the fruit skin. This possibly led to reduced fruit skin integrity that explains the higher sensitivity to develop lenticel damage.
  - Optimum irrigation is needed to ensure the elimination of water stress conditions that will have a negative effect on the photosynthetic output as well as maximum phloem transport of B from the leaves to the fruit. This implies that the important 6-7 weeks, as well as the weeks thereafter during fruit development, need optimum irrigation to ensure maximum fruit skin B content. Further research is needed to verify this finding.

Incidence of lenticel damage in relation to anthracnose decay (Table 8)

No interaction occurred between Factor A (orchard) and Factor B (handling stage) for anthracnose development. Significant differences were indicated between orchards.

• Generally, anthracnose development was low in 2020, due to it being a 2nd dry season in a row.
• Sampling point of fruits, related to additional handling when sourced from the pack-line, compared to minimal handling when sourced in the orchard, did not influence anthracnose.
• The incidence of anthracnose is highly dependent

on the inherent inoculum load in the orchard and the application of timeous fungicide sprays.

Incidence of lenticel damage in relation to stem-end rot (Table 8)

- No interaction occurred between Factor A (orchard) and Factor B (handling stage) for stem-end rot development. Significant differences were observed between orchards.
- 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 stem-end rot development, as expected as lenticel damage occurence on the skin.

Incidence of bruising (Table 9)

- A significant interaction occurred between Factor A (orchard) and Factor B (handling stage) for bruising.
- Generally, bruising is a function of how careful picking is done.
- Sampling point of fruit, related to additional handling when sourced from the pack-line compared to minimal handling when sourced in the orchard, was comparable, indicating that most pickers picked in a careful manner.
- Bruising differed between orchards for fruit sampled from the pack-line.
- The incidence of bruising was significantly higher for fruits of orchard [5] PH 2A 2019 and [9] PH2b 2019 compared to most other orchards.

Number of days for fruits to ripen (Table 9)

Table 7

- No interaction occurred between Factor A (orchard) and Factor B (handling stage) for days for fruits to ripen. Significant differences were indicated between orchards.
- Fruits from two optimum N orchards [2] PI S1B 2020 and [3] PI 43B ripened significantly slower compared to the other orchards.

Incidence of grey pulp (Table 10)

Table 8

- No grey pulp was recorded on avocados from any orchard.

Table 9: Incidence of bruising and number of days for fruits to ripen (DTR) of 'Hass' avocado fruits of 9 orchards for the difference between box-picked at harvest and fruits sampled from the pack-line in 2019 and 2020

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. PF1 2019	0.0a	0.0a	1.	PF1 2019	0.0a	0.694	1.7
2. PI S1B 2020	0.0a	0.0a	2.	PI S1B 2020	0.0a		
3. PI 43B 2020	1.3a	1.3a	3.	PI 43B 2020	1.3ab		
4. PG1 2019	0.0a	0.0a	4.	PG1 2019	0.0a		
5. PH2A 2019	0.0a	5.0bc	5.	PH2A 2019	2.5b		
6. PI S3A 2020	0.0a	0.0a	6.	PI S3A 2020	0.0a		
7. PI S2A 2020	2.5ab	0.0a	7.	PI S2A 2020	1.3ab		
8. PG 1 2020	2.5ab	2.5ab	8.	PG 1 2020	2.5b		
9. PH2B 2019	0.0a	6.3c	9.	PH2B 2019	3.1b		
	P < 0.0169			P < 0.0452		P < 0.0986	

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	Packhouse
1. PF1 2019	5.4	5.3	1.	PF1 2019	5.3cd	5.5	5.5
2. PI S1B 2020	6.1	6.1	2.	PI S1B 2020	6.1e		
3. PI 43B 2020	6.2	6.4	3.	PI 43B 2020	6.3e		
4. PG1 2019	5.6	5.6	4.	PG1 2019	5.6d		
5. PH2A 2019	4.3	4.6	5.	PH2A 2019	4.5a		
6. PI S3A 2020	5.0	4.9	6.	PI S3A 2020	4.9b		
7. PI S2A 2020	4.9	5.0	7.	PI S2A 2020	4.9b		
8. PG 1 2020	5.0	5.0	8.	PG 1 2020	5.1bc		
9. PH2B 2019	4.6	4.7	9.	PH2B 2019	4.5a		
	P < 0.962			P < 0.0000		P < 0.479	

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

Incidence of vascular browning (Table 10)
Table 8

- A significant interaction occurred between Factor A (orchard) and Factor B (handling stage) for vascular browning.
- Vascular browning was significantly higher for fruits of orchard [4] G1 2019, compared to all other orchards. Low B levels were recorded for this orchard.
- There was no vascular browning present in any of the 2020 orchards. This can be attributed to low pathogen presence due to 2 consecutive dry seasons, as vascular browning is usually related to stem-end rot.

TRIAL 2: To investigate if reduced irrigation followed by 5 weeks of no irrigation prior to harvest, provides protection/resistance towards the reduction of lenticel damage in an orchard with a high nitrogen level, proved to be sensitive to lenticel damage in 2019 (Objective 2)

Taking the current 2019's results into consideration a research need arose to alter the irrigation protocol in the three months prior to harvest, to try and copy Producer F's protocol of 5 weeks of no irrigation prior to harvest in a high N orchard (Producer G orchard 11):

- As high N stimulates increased growth and cell division that leads to larger cells with thinner cell walls, a period of reduced irrigation hypothetically would reduce growth and stimulate hardening of cell walls resulting in improved cell wall integrity.

Lenticel damage: Two-way ANOVA of 2 irrigation treatments (Table 11 and Fig. 4)

- No interaction occurred between Factor A (% weeks of no irrigation prior to harvest) and Factor B (fruit jostled or not).
- The jostling results indicated that the 5 weeks of no irrigation treatment of trees in a high N orchard led to similar total incidence of lenticel damage compared to the optimum irrigation treatment (86.33% and 89% respectively).
- The non-jostled treatment (Fig. 1a) showed a similar trend (48% and 66.8% respectively).
- Jostling exacerbated the occurrence of lenticel damage, irrespective of irrigation regime.

Table 10: Incidence of grey pulp and vascular browning of 'Hass' avocado fruits of 9 orchards for the difference between box-picked at harvest and fruits 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. PF1 2019	0.0	0.0	1. PF1 2019	0.0	0.0	0.0
2. PI S1B 2020	0.0	0.0	2. PI S1B 2020	0.0		
3. PI 43B 2020	0.0	0.0	3. PI 43B 2020	0.0		
4. PG1 2019	0.0	0.0	4. PG1 2019	0.0		
5. PH2A 2019	0.0	0.0	5. PH2A 2019	0.0		
6. PI S3A 2020	0.0	0.0	6. PI S3A 2020	0.0		
7. PI S2A 2020	0.0	0.0	7. PI S2A 2020	0.0		
8. PG 1 2020	0.0	0.0	8. PG 1 2020	0.0		
9. PH2B 2019	0.0	0.0	9. PH2B 2019	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	Packhouse
1. PF1 2019	0.0a	5.0c	1. PF1 2019	2.5	1.5	1.9
2. PI S1B 2020	0.0a	0.0a	2. PI S1B 2020	0.0		
3. PI 43B 2020	0.0a	0.0a	3. PI 43B 2020	0.0		
4. PG1 2019	12.5d	12.5d	4. PG1 2019	12.5		
5. PH2A 2019	1.3b	0.0	5. PH2A 2019	0.6		
6. PI S3A 2020	0.0	0.0	6. PI S3A 2020	0.0		
7. PI S2A 2020	0.0	0.0	7. PI S2A 2020	0.0		
8. PG 1 2020	0.0	0.0	8. PG 1 2020	0.0		
9. PH2B 2019	0.0	0.0	9. PH2B 2019	0.0		
	P < 0.0000		P < 0.0000		P < 0.0373	

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

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Incidence of lenticel damage in relation to fruit quality criteria (Table 11)

- No interaction occurred between Factor A (Jostled or not) and Factor B (Irrigation protocols) for anthracnose as well as stem-end rot development.
- The incidence of pathological disorders was very low in 2020, due to a 2nd dry season.
- No grey pulp or vascular browning was recorded.
- No interaction occurred between Factor A (Jostled or not) and Factor B (Irrigation protocols) for Nr of days to ripen.

Trial 3: Ca, B and Si foliar sprays

Lenticel damage: Two-way ANOVA of foliar application and jostling (Table 12)

Two-way analysis of variance (ANOVA) was applied on the data in Statistica (statistical software) using the LSD test (α = 0.05) to compare treatment means, for Factor A (jostling) and Factor B (foliar application).

A significant interaction occurred between Factor A (jostling of fruit) and Factor B (foliar application).

- Jostling of avocados resulted in higher levels of lenticel damage for the UTC, and treatments of Ca + B, as well as Ca + B followed by Si + B applications.
- Application of Ca + B + Si nutrient combination foliar spray treatment, applied 2.5 months prior to sampling, resulted in 13% reduction in the total incidence of lenticel damage (Fig. 2b) compared to the untreated control (62.7% and 72% respectively).
- Ca + B combination reduced lenticel damage by 4% compared to the UTC, but the decrease was not significant.
  - The lower percentage reduction of the latter indicates that absorption of Ca and B into the fruit skin was as effective as when Si was added to the combination spray.

Table 11: Fruit quality for samples procured from a high nitrogen orchard where 2 irrigation types were applied (T1: Stop irrigation 5 weeks prior to harvest and T2: Full irrigation), and subsequently at harvest the fruits 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 – GREY PULP							
Factor A (Jostle) x Factor B (Irrigation protocols)				Factor A (Jostle)		Factor B (Irrigation protocols)	
	Jostle	T1: Stop irrigation 5 weeks prior to harvest	T2: Full irrigation			T1: Stop irrigation 5 weeks prior to harvest	T2: Full irrigation
1.	Not Jostled	48.0a	53.3a	1. Not Jostled	50.6	66.33	70.66
2.	Jostled	86.7b	89.3b	2. Jostled	88.0		
		P < 0.766		P < 0.000		P < 0.151	
QUALITY PARAMETER – ANTHRACNOSE							
1.	Not Jostled	0.0	2.7	1. Not Jostled	1.3	0.7	2.0
2.	Jostled	1.3	1.3	2. Jostled	1.3		
		P < 0.426		P < 1.000		P < 0.426	
QUALITY PARAMETER – VASCULAR BROWNING							
1.	Not Jostled	0.0	1.3	1. Not Jostled	0.7	0.0	0.7
2.	Jostled	0.0	0.0	2. Jostled	0.0		
		P < 0.332		P < 0.332		P <0.332	
QUALITY PARAMETER – GREY PULP							
1.	Not Jostled	0.0	0.0	1. Not Jostled	0.0	0.0	0.0
2.	Jostled	0.0	0.0	2. Jostled	0.0		
		-		-		-	
QUALITY PARAMETER – VASCULAR BROWNING							
3.	Not Jostled	0.0	0.0	1. Not Jostled	0.0	0.0	0.0
4.	Jostled	0.0	0.0	2. Jostled	0.0		
				-		-	
QUALITY PARAMETER – No OF DAYS TO RIPEN							
1.	Not Jostled	5.7	5.3	1. Not Jostled	5.5	5.5	5.3
2.	Jostled	5.3	5.3	2. Jostled	5.3		
		P < 0.295		P < 0.295		P < 0.183	

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

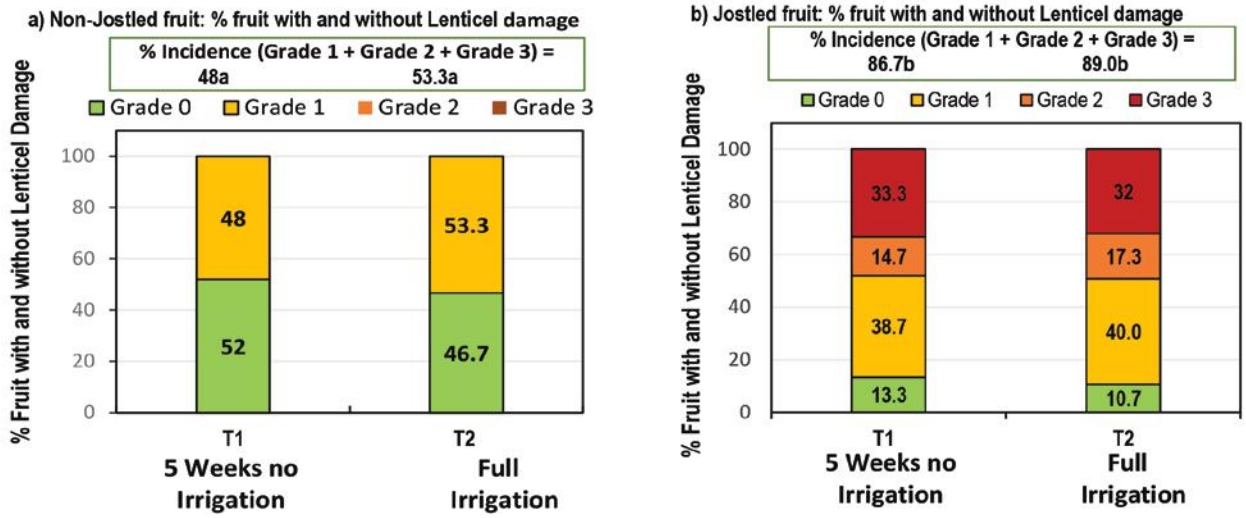

Figure 3: The percentage fruits with and without lenticel damage for fruit samples procured from a high nitrogen orchard with 2 irrigation treatments that included optimum irrigation and 5 weeks of no irrigation. The intensity of the disorder was quantified using PPECB's grading system (Grade 0 = sound, Grade 1, Grade 2 and Grade 3).

Table 12: Fruit quality for samples procured from a high nitrogen orchard where Ca, B and Si sprays were applied (T1-T4), and subsequently at harvest the fruits were either subjected to "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 - B - Si Foliar sprays)			Factor A (Jostle)		Factor B (Ca - B - Si Foliar sprays)		
Jostle	T1 UTC	T2 Ca + B	3 (Ca + B) +(Si + B)			T1 UTC	T2 Ca + B	T3 Ca + B +Si
3. Not Jostled	48.0a	49.3a	50.7a	1. Not Jostled	49.33	60.0	58.05	56.7
4. Jostled	72.0c	68.0bc	62.7b	2. Jostled	75.3			
		P < 0.025		P < 0.000			P < 0.288	
QUALITY PARAMETER – ANTHRACNOSE								
3. Not Jostled	0.0	0.0	1.3	1. Not Jostled	0.0	0.7	0.0	0.7
4. Jostled	1.3	0.0	1.3	2. Jostled	0.9			
		P < 0.613		P < 0.170			P < 0.613	
QUALITY PARAMETER – STEM-END ROT								
3. Not Jostled	1.3	0.0	0.0	1. Not Jostled	0.0	14.2	15.6	18.9
4. Jostled	0.0	0.0	0.0	2. Jostled	0.4			
		P < 0.383		P < 0.327			P <0.383	
QUALITY PARAMETER – GREY PULP								
5. Not Jostled	0.0	0.0	0.0	1. Not Jostled	0.0	0.0	0.0	0.0
6. Jostled	0.0	0.0	0.0	2. Jostled	0.0			
		-		-			-	
QUALITY PARAMETER – VASCULAR BROWNING								
1. Not Jostled	0.0	0.0	0.0	1. Not Jostled	0.0	0.0	0.0	0.0
2. Jostled	0.0	0.0	0.0	2. Jostled	0.0			
		-		-			P <0.403	
QUALITY PARAMETER – No OF DAYS TO RIPEN								
3. Not Jostled	5.2	5.3	5.3	1. Not Jostled	5.2	5.3	5.3	5.2
4. Jostled	5.3	5.3	5.2	2. Jostled	5.3			
		P < 0.781		P < 0.345			P < 0.525	

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

Table 13: Ca, B and Si content in fruit pulp and fruit skin, 3 months after conducting the foliar nutrient sprays in an orchard of high nitrogen

Treatments		Ca (%)		B (mg/kg)		Si (mg/kg)	
		Pulp	Skin	Pulp	Skin	Pulp	Skin
T1	UTC	0.08	0.13	32	34	722	854
T2	Ca + B	0.10	0.14	35	36	758	842
T3	(Si + B) & (Ca + B)	**0.14**	**0.22**	**48**	**42**	**1058**	**950**

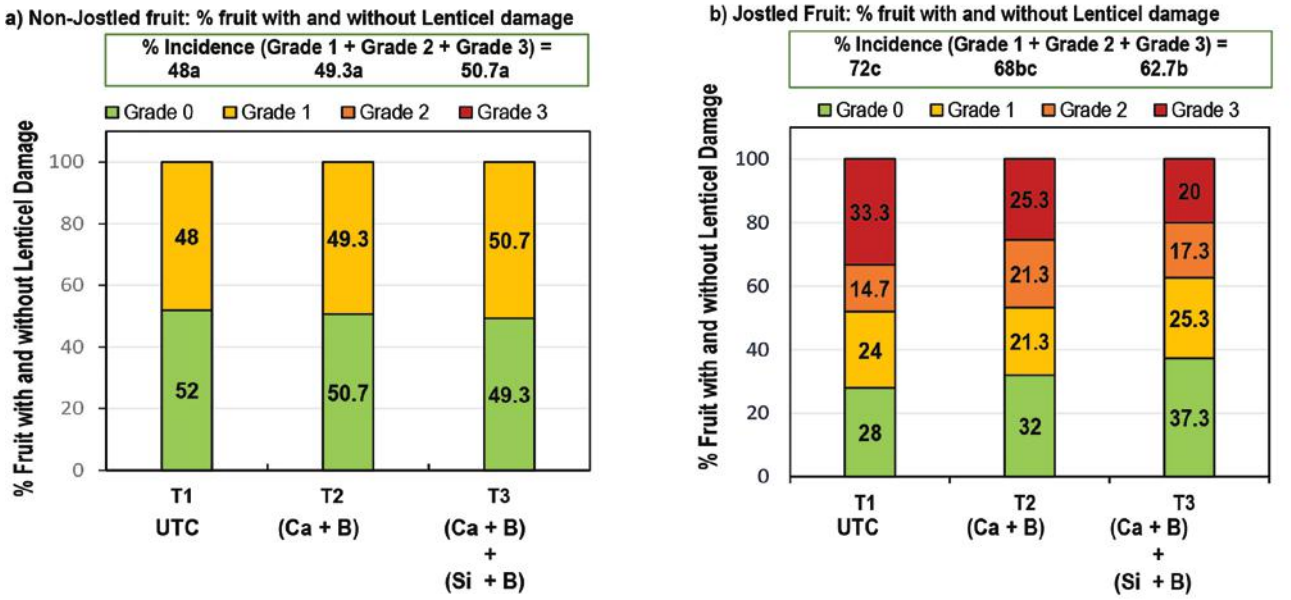

Figure 4: The percentage fruits with and without lenticel damage for fruit samples procured from a high nitrogen orchard with 3 Ca + B combination nutrient foliar spray treatments (21 day, 7 day intervals), with and without 2 Si foliar spray treatments that were applied 1 day before and 1 day after the combination treatments. The intensity of the disorder was quantified using PPECB's grading system (Grade 1, Grade 2 and Grade 3) (Grade 0 = sound fruit).

- The non-jostled treatments obtained similar results for the untreated control and the two spray treatment (48%, 49.3% and 50.7% respectively).
- The results with Ca + B + Si foliar sprays are promising and should be pursued in future research.

Fruit skin and pulp nutrient analysis

- The fruit skin results confirmed that the Ca + B combination sprays did not increase the pulp and skin Ca and B content. This indicates that these nutrients were not effectively absorbed into the fruit skin.
- The combination sprays of Si + B and Ca + Boron increased both pulp and skin Si content (1058 mg/kg and 950 mg/kg for pulp and skin, respectively, compared to 722 mg/kg and 854 mg/kg for the UTC).
- The Si + B and Ca +B combination sprays also increased both pulp and skin Ca content (0.14% and 0.22% for pulp and skin respectively, compared to 0.08% and 0.13% for the UTC).
- Furthermore, the Si + B and Ca + B combination sprays also increased both pulp and skin B content (48 mg/kg and 42 mg/kg for pulp and skin respectively, compared to 0.08% and 48 mg/kg and 42 mg/kg).

CONCLUSIONS

- The irrigation treatment including a 5 week period of no irrigation applied in a high nitrogen orchard, did not reduce the incidence of lenticel damage compared to the optimum full irrigation treatment. This excludes the possibility of reduced irrigation being the major contributing factor to explain orchard F's pronounced resistance to develop lenticel damage in 2019.
- Orchard S1B 2020, with optimal leaf N, Ca and B values similar to orchard PF1 2019, exhibited lenticel damage compared to high N orchards.
- There is a dramatic increase in lenticel damage when high N orchards are not in adherence to the soil moisture protocol. During the two years of research, unfortunately no optimum nitrogen orchards were harvested at wet soil moisture to make a full comparison.
- Suboptimal irrigation may limit the root uptake of Ca and B through transpiration, and hence limit the integrity of fruit skin, adding to increased sensitivity to lenticel damage.
  - This emphasises the importance of optimum irrigation during the first 6-7 weeks of fruit development to ensure that Ca and B accumulate optimally in the fruit skin.

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- An orchard ([1] PF1 2019) with optimum leaf N, Ca, Mg and B was able to accumulate B in the fruit skin with a value that was ± 100% higher than the leaf B value obtained with the least lenticel damage.
  - This partly explains this orchard's remarkable resistance to develop lenticel damage.
  - This very high skin B content could only have been obtained with optimum photosynthetic output in place to ensure enough available Perseitol that acts as carrier of B during phloem transport.
- An orchard ([2] PI S1B 2020) with optimum leaf N, Ca, Mg and B very similar to [1] PF11 2019 in contrast could only accumulate B in the fruit with a value that was only ± 6 higher than the leaf B value.
  - This explains the sensitivity of this orchard to develop lenticel damage when compared to [1] PF11 2019.
  - This implicates that photosynthetic output was inhibited during fruit development that led to less Perseitol available to act as carrier. This influenced the effective and optimum phloem transport of B to the fruit skin. This possibly led to reduced fruit skin integrity that explains the higher sensitivity to develop lenticel damage.
- The 3x Ca + B combination, nutrient foliar spray treatments, applied along with 2 Si + B foliar nutrient spray treatments 3 months prior to harvest, reduced the total incidence of lenticel damage of 'Hass' fruit by ± 13%, despite the fruit being procured from a high N orchard.
- Further research should focus on the best application time and to increase the number of applications, in an attempt to increase the effectivity of the Si treatment. In this regard, applications earlier in fruit development may increase the Si, as well as Ca and B absorption into the fruit skin. In other crops the Si foliar sprays are effectively combined with a preceding Si soil application to increase efficacy.

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