Commercial-in confidence

Effect of Seasol® fertigation on post-harvest quality of avocado

FreshHort

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FreshHort is an independent R&D consulting company with over 50 years of experience in horticultural R&D encompassing trial design and statistical analysis, evaluation of postharvest supply chains, technologies, and treatments, and postharvest disease control. We also provide fresh produce handling and quality assessment training to the fruit and vegetable industry, and to fresh food retailers.

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Summary

Flesh dry matter concentration, skin colour, flesh firmness, and external and internal disorders, are the main indicators of avocado quality and maturity (i.e., ripeness) during post-harvest handling and ripening. DM is a good indicator of fruit maturity with higher DM in flesh usually resulting in better storage potential and eating quality after ripening. After harvest avocados may be stored for more than two weeks prior to the commencement of ripening particularly if fruit has been exported. Avocado fruit may also be prone to physiological disorders or rot development during ripening particularly if fruit have been stored for extended periods after harvest. Thus any treatment that increases DM in avocado flesh, reduces loss of green colour, and reduces loss of flesh firmness during storage, and prevents physiological disorders and rots during ripening, will be of commercial importance.

A previous study in the 2017 season demonstrated the beneficial effects of Seasol® fertigation on postharvest quality of avocados (Lopresti et al., 2017). The results from the current trial repeated in the 2018 season largely confirmed those initial findings whilst also demonstrating that Seasol® fertigation can reduce fruit susceptibility to stem end rot and cheek rot in fruit harvested under wet conditions with a higher risk of infection during ripening. In the current trial Seasol® treatment via fertigation improved postharvest quality and reduced rot development in mid-season Shepard avocado after storage for 21 days at 7°C, and after ripening both at harvest, and out of cool storage. In the 2018 season fruit were harvested under wet orchard conditions resulting in treated and untreated fruit with a lower harvest quality than in 2017 and with a higher risk of postharvest rots.

Whilst no significant difference in mean weight was found between treated and untreated fruit, dry matter (DM) concentration in avocado flesh was consistently and significantly higher in fruit treated with Seasol®, with an average increase in DM of 2% in treated fruit after ripening compared to control fruit. Flesh dry matter concentration is an important indicator of eating quality in avocado with higher DM improving flavour, nutritional value and storage potential of fruit. In 2017 no significant difference in DM was observed between treated and control Hass avocado fruit that was harvested approximately one week earlier than in 2018 and was approximately 4% lower in DM. Fruit firmness averaged over all assessments was significantly higher in Seasol® treated fruit as measured by both hand pressure and skin shore hardness, and these results are consistent with those obtained in 2017, although differences in firmness among treated and control fruit were smaller in the 2018 trial. In both years the positive effect of Seasol® treatment on fruit firmness was most apparent after ripening, whether at harvest or after storage. Flesh firmness averaged over all assessments was also significantly higher in Seasol® treated fruit as measured by flesh shore hardness with treated fruit remaining significantly firmer than control fruit by an average of 7 shore hardness units during storage for 21 days at 7°C. Possibly due to lower quality fruit at harvest flesh firmness measured after storage in 2018 was approximately 40 shore hardness units softer among both treated and untreated fruit compared to fruit at the same assessment in 2017. Two seasons of trials have demonstrated that Seasol® fertigation treatment reduces firmness loss in avocado during cool storage, and during ripening both at harvest and after storage, a result that is of commercial importance, when fruit is cool-stored prior to marketing, and in maintaining better fruit quality during retailing.

No significant difference in fruit skin colour as measured via hue angle was found among treated and control fruit with both having similar skin colour at harvest and throughout storage and ripening, although all fruit were significantly less green and darker after storage and ripening. On the other hand in the 2017 trial treated fruit were significantly greener than control fruit after storage and ripening suggesting that the 2018 results may have been confounded by skin spotting, and lower quality and darker fruit after ripening among all fruit assessed. Visual quality of Seasol® treated fruit as measured by skin colour rating was significantly higher than control fruit after ripening at both Day 0 and out of storage, but no difference in visual quality was found after 21 days storage at 7°C. As in 2017, when averaged across all assessments, treated fruit had significantly higher visual quality than control fruit, and had consistently better visual quality at all assessments. Although visual quality of all fruit was lower in 2018 compared to that in 2017, due to skin spotting and high incidence of skin discrete darkening, two seasons of trials have demonstrated that Seasol® fertigation treatment consistently reduces visual quality loss during postharvest storage and ripening.

In the 2018 trial relatively high incidence of stem end rots were observed in both treated and control fruit compared to 2017 where no significant difference in stem rots was found among treated and control fruit. In the current trial Seasol® fertigation resulted in significantly lower rot incidence after ripening at Day 0, and a commercially-important but non-significant reduction in stem rot after ripening out of storage. Across both ripening assessments treated fruit had approximately 30% lower stem end rot incidence than control fruit. The current trial also confirmed that Seasol® treatment reduces stem end rot severity when averaged across all assessments, and in both seasons significantly reduced stem rots after ripening. No fruit cheek rots were observed in the 2017 season but in 2018 cheek rots were observed at both ripening assessments with control fruit having significantly higher rot incidence and severity than control fruit after storage and ripening. After ripening at Day 0 treated fruit had lower rot incidence that wasn't significantly different but still may have commercial importance as Seasol® treatment reduced cheek rot by 8% at this assessment.

In 2017 incidence of flesh browning in fruit after storage and ripening was relatively low with Seasol® treatment significantly reducing browning incidence and severity after storage and ripening. In 2018 high flesh browning incidence and moderate browning severity were observed among both treated and control fruit, and both incidence and severity increased with postharvest storage and subsequent ripening. After storage for 21 days at 7°C all fruit assessed had flesh browning symptoms with no significant difference in browning severity among treated and control fruit. Again wet harvest conditions may have been a cause of the higher susceptibility to flesh browning observed in the 2018 trial.

Similar experiments conducted over two seasons to determine the effect of Seasol® fertigation treatment on postharvest quality of avocado have confirmed that treated fruit:

- Remain firmer during storage and ripening, and loss of visual quality is reduced, when compared to untreated fruit;
- May have higher flesh dry matter during postharvest storage when fruit are harvested later in the season;

- Have lower stem end rot incidence and severity during postharvest storage and ripening, and treatment seems to be effective in significantly reducing rot development in high risk fruit;
- Have lower cheek rot incidence and severity during storage and ripening in seasons where harvest was conducted under wet orchard conditions.

Seasol® fertigation treatment has a beneficial impact on postharvest quality of avocados by reducing rot development during storage and marketing, improving visual quality of fruit and reducing loss of firmness in fruit. These improvements in avocado quality are commercially important to growers, exporters and retailers, potentially resulting in an extended marketing period, higher quality fruit after cool storage, reduced rots after storage and ripening, and greater consumer satisfaction.

Scientific recommendations

Based on two seasons of experiments showing that Seasol® fertigation improves avocado quality and shelf life it is recommended that future studies focus on:

- One more season of experiments to further confirm the beneficial effects of Seasol® fertigation on avocado quality particularly dry matter concentration, and to determine its potential to reduce physiological disorder such as flesh browning under typical harvest orchard conditions.

- Conducting experiments to determine the effect of Seasol® treatment in reducing chilling injury (i.e., flesh disorders, skin darkening) during avocado cool storage as a significant proportion of fruit grown in Australia is likely to be handled and stored at chilling temperatures below 5°C during domestic wholesaling and retailing.

- Understanding the biochemical and physiological mechanisms that inhibit firmness loss and reduce susceptibility to rots among avocados treated with Seasol®, potentially via collaboration with a university, as there appears to be a consistent reduction in firmness loss during postharvest storage across treated temperate fruit crops studied so far.

Experimental objectives

1. Investigate the effect of Seasol® fertigation on visual quality, flesh firmness and composition of mid-season Shepard avocado at harvest;
2. Determine the effect of Seasol® fertigation on mid-season Shepard avocado postharvest storage quality and ripening behaviour;
3. Determine whether Seasol® fertigation reduces incidence and severity of physiological disorders in avocado during postharvest storage.

Experimental methods

Field trial and Seasol® fertigation

A single field trial was conducted to investigate the influence of Seasol® on yield of avocados cv. Shepard. Monthly applications of Seasol® were made from flowering until harvest, via under tree micro-sprinkler irrigation. The trial was conducted on a commercial avocado farm at Paddy's Green, Mareeba, on the Atherton Tablelands, in far north Queensland, Australia.

The trial was conducted using a large block, single replicate design with two treatments. A single block of six hectares was divided in half and 3 hectares were randomly allocated to Seasol® treatment, and the other 3 hectares remained untreated throughout the trial. Trees were 12 years old and growing in a typical, local agricultural soil type (red clay loam) that was uniform across both treatments. Similar crop management (i.e., irrigation timing and amounts, nutrition and pest control) operations were applied across both treatments. The whole trial block was infected with Phytophthora cinnamomi with moderate to severe symptoms ranging from light defoliation to heavy defoliation and tree death.

Seasol® was applied via under-tree micro-sprinkler irrigation at monthly intervals at 10 L/ha as part of the normal farm irrigation program. The required amount of Seasol® (30 litres) was mixed with 600 litres of water, which was pumped through the irrigation system, until evenly distributed throughout the treated block. Equal amounts of water and other management inputs were applied to trees in both treatment blocks. From eight trees used in the fertigation field experiment 20 fruit per tree were randomly selected

Fruit harvest, delivery and preparation

From eight trees used in the fertigation field experiment 20 fruit per tree were randomly selected after all fruit were graded to commercial market standards. On the 6rd April 2018 one standard tray of fruit from each tree was delivered to John Lopresti in Melbourne. On arrival all fruit were placed in unsealed high humidity bags at 18°C and 70% RH. Within 24 hours of delivery fruit had reached a pulp temperature of 18°C. Fruit within each tray were then segregated into four groups of five fruit and each group randomly assigned to a harvest and storage assessment.

Experimental design

Avocado fruit were obtained from a large non-replicated field trial with one block of trees fertigated with Seasol® during fruit development and another block irrigated as normal (i.e., Control block). Both experimental field blocks had similar soil type and crop management inputs. Assuming that the two field blocks used were homogeneous the experiment could be considered a fully randomised design with one replicate per treatment. At harvest four trees of similar age, size and health were randomly selected as sampling units in each field block. The experimental unit in the trial was the field block with each of four trees within a block representing a sampling unit from which 20 fruit were selected for harvest and storage quality assessments. Upon delivery and warming to 18°C fruit from each tree were segregated into four groups of five fruit and each group was allocated to one of the following assessments where Day 0 refers to the first day of the experiment:

A. Day 0 (unripened fruit)
B. Day 0 + ripening for 5 days
C. Storage at 7°C for 21 days
D. Storage + ripening for 3 days

Statistical analyses

To determine the main and interaction effects of fertigation and assessment on fruit quality and physiological disorders, data were analysed as a factorial experiment with no blocking using two-way ANOVA in GenStat 17 (VSN International Ltd., Oxford, UK).

Violations of the ANOVA assumption of normality in the data, such as non-normality (Skewness, Kurtosis) or heterogeneity of treatment variance, were assessed using residual error plots, skewness and kurtosis tests of normality, and Bartlett's test of homogeneity of variance. Where necessary the appropriate data correction transformation was applied to data prior to ANOVA based on optimal values of lambda calculated from Box-Cox analysis in Genstat.

A two-way analysis of variance (ANOVA) with no blocking was performed to determine main treatment and interaction effects. Multiple comparisons of treatment means were conducted at each assessment using Fisher's Least Significant Difference (LSD) test with statistical differences between means determined at a 5% significance level ($\alpha = 0.05$). Note that in the report the term 'significant' refers to statistical significance rather than to effects that may be commercially significant. Treatment means that were back-transformed from transformed data used for ANOVA are indicated in results tables.

Postharvest storage and ripening

Groups of fruit selected for postharvest assessment were stored in a cool room for 21 days in trays within unsealed high humidity liners at 7°C and 90% RH. Fruit were ripened after harvest and postharvest storage in a cool room at 18°C and 70% RH. After harvest and postharvest storage ripening was completed in 5 and 3 days, respectively.

Fruit assessments

At each assessment the following quality attributes were measured among five fruit per tree:

- Weight (using standard scales to one decimal place)
- Visual skin colour score
- Fruit surface colour (hue angle)
- Hand pressure firmness score
- Fruit skin and flesh firmness
- Flesh dry matter concentration
- Skin and flesh physiological disorders
- Fruit rots

The specific methods and scoring used to measure each fruit quality attribute are described below based on White et al., (2003) but methods modified to improve precision where necessary.

Both the mean incidence and severity of physiological disorders and flesh rots were calculated based on five fruit per tree per assessment.

Fruit quality

Visual skin colour score

A five-point rating scale was used to describe skin colour (Fig. 1) where 1= Emerald green and shiny; 2 = Forest green and not shiny; 3 = Black on green (approx. 20 to 30% dark); 4 = Green on black (approx. 60 to 70% dark); and 5 = Black (> 70% dark). Half ratings were used where necessary for a more precise skin colour score (e.g., 2.5).

Figure 1. Visual skin colour rating scale used during avocado assessments (1 = left; 4 = right).

Fruit surface colour

Skin surface colour was measured on both cheeks of each fruit at its widest point with a hand-held tristimulus reflectance colorimeter (model CM-2600d, Minolta Corp.). Colour was recorded using the CIE L*a*b* uniform colour space (CIE Laboratories), where L* indicates lightness, a* indicates chromaticity on a green (-) to red (+) axis, and b* chromaticity on a blue (-) to yellow (+) axis. Numerical values of a* and b* for each fruit were averaged and then the average hue angle calculated using $H° = \arctan(b^*/a^*)$.

Hand pressure firmness

The deformation or 'give' of the whole fruit was determined by holding the fruit in the palm of the hand and gently squeezing with the whole hand if the fruit was soft, or with the fingers and thumb when fruit was hard. Each fruit was then given a firmness score based on the rating scale in Figure 2.

The 'give' or deformation of the fruit is rated using the following scale

0 =	Hard, no 'give' in the fruit
1 =	Rubbery, slight 'give' in the fruit
2 =	Sprung, can feel the flesh deform by 2-3 mm under extreme thumb force
3 =	Softening, can feel 2-3 mm deformation with moderate thumb pressure
4 =	Near-ripe, 2-3 mm deformation achieved with slight thumb pressure, whole fruit deforms with extreme hand pressure
5 =	Ripe or eating soft, whole fruit deforms with moderate hand pressure
6 =	Overripe, whole fruit deforms with slight hand pressure
7 =	Very overripe, flesh feels almost liquid.

Figure 2. Hand pressure firmness rating scale.

Durometer fruit firmness

At each assessment fruit firmness was measured on both cheeks of each fruit at its widest point with a hand-held Agrosta® Durofel DFT 100 digital firmness tester using the Shore A hardness 0 to 100 scale where 0 = extra soft, 20 = soft, 40 = medium soft, 70 = medium hard and >90 = hard. After removal of the skin on each cheek the same firmness measurement was conducted on the flesh of the fruit. During firmness measurements soft spots on fruit were avoided. The firmness tester was calibrated to zero prior to measurements at each assessment.

Flesh dry matter (DM) concentration

After flesh firmness measurements were completed the cheek of each side of a fruit was sliced off, skin peeled off, and the flesh trimmed down to approximately 15 g. Flesh pieces were then weighed, placed in cups within a plastic tray, and dried to constant weight at 65°C. Dried avocado cheeks were then weighed again and the dry matter concentration calculated.

Physiological disorders and rots

Stem end rot

A four-point rating scale was used to describe stem end rot severity where 0 = none; 1 = slight; 2 = moderate; and 3 = severe (Fig. 3). On examination of flesh of fruit with stem end browning, no flesh browning or rot was observed thus this disorder was categorised separately to that assessed as stem end rot.

Figure 3. Stem end rot rating scale where 0 = none (1 = left; 2 = middle; 3 = right).

Discrete skin darkening

A four-point rating scale was used to describe severity of discrete darkening (patches) of fruit skin where 0 = none; 1= 10% of surface; 2 = 25% of surface; and 3 = 50% of surface (Fig. 4). Half ratings were used where necessary for a more precise skin colour score (e.g., 1.5).

Figure 4. Discrete skin patch rating scale where 1 = none (2 = left; 3 = middle; 4 = right).

Skin spotting

A five-point rating scale was used to describe severity of fruit skin spotting where 0 = none; 1= 10% of surface; 2 = 20% of surface; and 3 = 40% of surface; 4 = 60% of surface; and 5 = 80% of surface (Fig. 5). Half ratings were used where necessary for a more precise scoring of skin spotting (e.g., 3.5).

Figure 5. Skin spotting rating scale (1 = left; 3 = middle; 5 = right).

Diffuse flesh browning

A four-point rating scale was used to describe severity of diffuse flesh discolouration and browning not associated with rots, where 0 = none; 1 = 10% of flesh; 2 = 25% of flesh; and 3 = 50% of flesh (Fig. 6). Half ratings were used where necessary for a more precise scoring of flesh browning (e.g., 1.5).

Figure 6. Diffuse flesh discolouration rating scale (0 = none; 1 = slight; 2 = moderate; 3 = severe).

Cheek rot

A four-point rating scale was used to describe cheek rot severity in fruit where 1 = none; 2 = slight; 3 = moderate; and 4 = severe (Fig. 7). Half ratings were used where necessary for a more precise scoring of stem end rot (e.g., 2.5). External cheek rot was distinguished from discrete darkening by assessing flesh directly under the external rot.

Figure 6. Cheek rot rating scale (1 = none; 2 = slight; 3 = moderate; 4 = severe).

Results & Discussion

Presentation of results

For each quality factor measured during fruit assessments Analysis of Variance (ANOVA) results are presented in a consistent format where mean values for treated and control fruit are shown at each assessment i.e., Day 0, after storage (Day 21), after ripening at Day 0 (Day 0 + Ripe) and after storage and ripening (Day 21 + Ripe). Three *P*-values from ANOVA are provided in each table where a value of $P < 0.05$ indicates a statistically significant effect. In each table 'Treatment *P*-value' indicates whether Seasol® treatment is significantly better than no treatment. 'Assessment *P*-value' indicates whether the time of assessment has an effect on quality when the average of the two treatments are combined. Finally 'Treatment x Assessment *P*-value' indicates whether there is an interaction between treatment and assessment, that is whether any differences between treatments are consistent across assessments or not, with $P < 0.05$ indicating that the time of fruit removal influences the size of the observed difference, if any, between treated and control fruit.

Fruit mass

No significant difference in fruit weight was found among treated and control fruit with Day 0 fruit having a mean weight of approximately 225 g. Mean fruit weight was lowest among both treatments most likely due to water loss after 21 days of storage at 7°C and ripening for 3 days at 18°C (Table 1).

Table 1. Treatment effect on mean fruit mass among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Fruit mass (g)			
Treatment	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	225 a	228 a	226 a	216 a
Control	225 a	233 a	224 a	218 a
Treatment *P*-value	0.945			
Assessment *P*-value	0.960			
Treatment x Assessment *P*-value	0.999			

Flesh dry matter

Treated fruit were consistently higher in flesh dry matter (DM) than untreated fruit and significantly higher in DM when averaged across all assessments, and also after ripening at Day 0 (Table 2). Across all assessments mean DM in treated fruit was 1.3 % greater than among control fruit whilst DM after ripening assessments at day 0 and after storage was 2.9 % and 1.1 % higher, respectively, in treated fruit.

Table 2. Treatment effect on mean flesh dry matter concentration among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Flesh dry matter (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	30.3 a	30.8 a	29.6 a	31.4 a	29.4 a
Control	29.0 b	30.5 a	29.0 a	28.5 b	28.3 a
Treatment *P*-value	0.002				
Assessment *P*-value	0.010				
Treatment x Assessment *P*-value	0.075				

Fruit firmness

At Day 0 hand pressure firmness score was zero in both treated and control fruit whilst fruit softened marginally during storage for 21 days at 7°C with no significant difference in mean hand firmness between treated and control fruit (Table 3). Treated fruit were significantly firmer when averaged across all assessments and remained significantly firmer after storage for 21 days and ripening for 3 days.

Table 3. Treatment effect on mean hand pressure firmness score among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Hand pressure firmness score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	2.1 a	0 a	1.6 a	3.6 a	3.1 a
Control	2.5 b	0 a	2.1 a	3.9 a	4.0 b
Treatment *P*-value	0.003				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.105				

At Day 0 mean shore hardness score measured on fruit skin was 100 among both treated and control whilst treated fruit had consistently and significantly greater firmness, by 4 to 6 shore hardness units, after ripening at Day 0, storage for 21 days at 7°C and after storage and ripening (Table 4). When averaged over all assessments treated fruit were significantly firmer than control fruit by an average of 4 shore hardness units.

Table 4. Treatment effect on fruit skin shore hardness score among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Skin shore hardness score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	89 a	100 a	89 a	79 a	88 a
Control	85 b	100 a	85 b	74 b	82 b
Treatment *P* -value	0.003				
Assessment *P* -value	<0.001				
Treatment x Assessment *P* -value	0.269				

At Day 0 mean shore hardness score measured on fruit flesh was 98 and 97 among treated and control fruit respectively whilst treated fruit had consistently and significantly greater firmness, by 2 to 8 shore hardness units, after ripening at Day 0, storage for 21 days at 7°C and after storage and ripening (Table 5). When averaged over all assessments flesh of treated fruit was significantly firmer than control fruit by an average of 5 shore hardness units. Flesh firmness fell significantly after storage, and ripening at both Day 0 and after storage.

Table 5. Treatment effect on fruit flesh shore hardness score among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Flesh shore hardness score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	45 a	98 a	36 a	16 a	30 a
Control	40 b	97 a	29 b	14 a	22 b
Treatment *P* -value	0.001				
Assessment *P* -value	<0.001				
Treatment x Assessment *P* -value	0.154				

Fruit skin colour

At Day 0 mean skin colour was 2.0 among both treated and untreated fruit based on visual quality scoring with no significant difference in skin colour among treated and control fruit after storage for 21 days at 7°C (Table 6). Treated fruit were significantly greener than untreated fruit after ripening at Day 0 and after storage, and when averaged over all assessments skin colour was significantly greener among control fruit compared to treated fruit due to higher levels of darkening in control fruit as a result of cheek rots. Thus visual scoring of fruit colour was a reasonable measure of overall visual quality of fruit.

Table 6. Treatment effect on fruit skin colour score among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at *P* < 0.05.

	Skin colour score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	2.5 a	2.0 a	2.5 a	2.7 a	3.0 a
Control	3.0 b	2.0 a	2.6 a	3.5 b	4.0 b
Treatment *P*-value	0.008				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.100				

At Day 0 mean skin colour as measured by hue angle was similar among treated and control fruit and did not differ significantly after ripening and storage (Table 7). Skin coloured darkened during fruit ripening but little difference in colour was found among treated and control fruit.

Table 7. Treatment effect on fruit skin colour as measured via hue angle among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at *P* < 0.05.

	Skin hue (°)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	121 a	124 a	121 a	119 a	120 a
Control	121 a	123 a	121 a	118 a	120 a
Treatment *P*-value	0.275				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.754				

Fruit rots and physiological disorders

Averaged across all assessments stem end rot incidence was significantly lower among treated fruit with rot incidence 16 % higher on average among control fruit (Table 8). Stem end rot incidence was also significantly greater in control fruit after ripening both at Day 0 and after storage, by 35 % and 25% respectively, whilst no significant difference was found among treated and control fruit after storage for 21 days at 7°C. Although after ripening control fruit had 3 to 4 times the incidence of stem end rots compared to treated fruit these differences were only significant after ripening at Day 0 due to relatively high variability in rot incidence among replicates within each treatment.

Table 8. Treatment effect on incidence of fruit stem end rot among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at *P* < 0.05.

	Stem rot incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	10 a	0 a	21 a	10 a	10 a
Control	26 b	0 a	25 a	45 b	35 a
Treatment *P*-value	0.043				
Assessment *P*-value	0.065				
Treatment x Assessment *P*-value	0.303				

Mean stem end rot severity was relatively among both treated and control fruit when averaged across all fruit within a replicate but stem end rot severity was still significantly lower than in control fruit when averaged across all assessments, and after storage and ripening (Table9).

Table 9. Treatment effect on severity of fruit stem rot among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at *P* < 0.05.

	Stem rot severity score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	0.2 a	0 a	0.6 a	0.1 a	0.1 a
Control	0.4 b	0 a	0.7 a	0.5 a	0.6 b
Treatment *P*-value	0.044				
Assessment *P*-value	0.008				
Treatment x Assessment *P*-value	0.374				

No skin discrete patches were observed among treated and untreated fruit at Day 0 whilst discrete patch incidence varied among treated and control fruit with no consistent reduction in this disorder due to Seasol® treatment (Table 10). Discrete patch incidence was relatively high and similar among treated and control fruit although after ripening at Day 0 incidence in control fruit was 54% higher but this difference was not statistically significant due to the overall treatment *P*-value being greater than 0.05. Severity of skin discrete patch was moderate among both treated and control fruit with very little difference in severity score among assessments (Table 11). Discrete patch severity tended to increase during ripening at Day o and after storage in both treated and control fruit.

Table 10. Treatment effect on incidence of skin discrete patch among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Skin discrete patch incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	55 a	0 a	89 a	30 a	100 a
Control	61 a	0 a	70 a	84 a	90 a
Treatment *P*-value	0.210				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	<0.001				

Table 11. Treatment effect on severity of skin discrete patch among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Skin discrete patch severity score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	2.1 a	1.0 a	2.4 a	1.6 a	2.4 a
Control	2.1 a	1.0 a	2.5 a	2.2 a	2.5 a
Treatment *P*-value	0.926				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.065				

At each assessment no significant difference in skin spot was found among treated and control fruit although in all cases this disorder was slightly higher in treated fruit with the difference in skin spot severity at Day 0 similar to that observed at all other assessments (Table 12). When averaged across all assessments treated fruit had significantly higher skin spot than control fruit but this relatively small difference in severity was very likely due to wet weather conditions during the harvest period and unrelated to Seasol® treatment.

Table 12. Treatment effect on severity of skin spot among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Skin spot severity score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	2.3 a	2.1 a	2.1 a	2.7 a	2.3 a
Control	2.0 b	1.7 a	1.9 a	2.4 a	2.0 a
Treatment *P*-value	0.037				
Assessment *P*-value	0.007				
Treatment x Assessment *P*-value	0.797				

At each assessment no significant difference in flesh browning incidence and severity was found among treated and control fruit with incidence (Table 13) and severity (Table 14) of browning increasing significantly after storage among both treated and control fruit, and with relatively high browning incidence averaged over all assessments.

Table 13. Treatment effect on incidence of flesh browning among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Flesh browning incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	53 a	0 a	100 a	10 a	100 a
Control	56 a	0 a	100 a	25 a	100 a
Treatment *P*-value	0.382				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.509				

Table 14. Treatment effect on severity of flesh browning among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Flesh browning severity score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.0 a	0 a	2.1 a	0.1 a	1.9 a
Control	1.1 a	0 a	2.0 a	0.3 a	2.1 a
Treatment *P*-value	0.628				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.790				

At Day 0 and after storage for 21 days at 7°C no fruit cheek rot was observed among both treated and control fruit whilst ripening at Day 0 and after storage resulted in disease expression among both treated and control fruit (Table 15). After ripening at Day 0 control fruit had 8% higher rot incidence which was not found to be statistically significant but after storage and ripening treated fruit had significantly less cheek rots, with 100% of control fruit with cheek rot symptoms. Similarly severity of cheek rot was significantly greater among control fruit after storage and ripening (Table 16).

Table 15. Treatment effect on incidence of cheek rot among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at $P < 0.05$.

	Cheek rot incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	16 a	0 a	0 a	5 a	60 a
Control	28 b	0 a	0 a	13 a	100 b
Treatment *P*-value	0.008				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.006				

Table 16. Treatment effect on severity of cheek rot among fruit assessed at day 0 and after storage, both at removal and after ripening; different letters indicate a statistically significant difference at *P* < 0.05.

	Cheek rot severity score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.2 a	1.0 a	1.0 a	1.1 a	1.9 a
Control	1.6 b	1.0 a	1.0 a	1.1 a	3.4 b
Treatment *P*-value	0.004				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	<0.001				

Conclusions

Two seasons of postharvest trials to determine the effect of Seasol® fertigation on avocado quality have demonstrated that treatment significantly reduces fruit softening, improves visual quality and reduces skin darkening, and reduces incidence of stem end and cheek rot. The differences in fruit quality among treated and untreated fruit are most apparent after ripening, both directly after harvest and after three weeks of cool storage to simulate extended domestic storage or export shipments. In the 2018 trial Seasol® fertigation also significantly reduced fruit susceptibility to stem end rot and cheek rot in fruit harvested under wet conditions with a higher risk of infection during ripening. Dry matter concentration in avocado flesh was also significantly higher among treated fruit in 2018. Higher dry matter concentration in avocados has been associated with greater fruit storage potential and better flavour and eating quality.

Postharvest quality of avocados is clearly improved by using Seasol® fertigation prior to harvest with an extended marketing period possible due to the reduction in rate of fruit softening and loss of visual quality in treated fruit. Reducing rot incidence and severity in avocados is obviously critical in reducing wastage during storage and marketing whilst also resulting in greater retailer and consumer confidence that they are receiving and consuming a high quality product with reasonable shelf-life during ripening.

References

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Appendix

Avocado quality images

Avocado visual quality at day 0 (Top = control fruit; Bottom = Seasol treated fruit).

Avocado visual quality at day 0 after ripening for 5 days (Top = control fruit; Bottom = Seasol treated fruit).

Avocado visual quality at day 21 after cool storage (Top = control fruit; Bottom = Seasol treated fruit).

Avocado visual quality at day 21 after cool storage and ripening (Top = control fruit; Bottom = Seasol treated fruit).

Avocado internal quality at day 21 after cool storage and ripening (Top = control fruit; Bottom = Seasol treated fruit).