Commercial-in confidence

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

FreshHort

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Author: FreshHort

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Summary

A preliminary experiment was conducted to determine the effect of Seasol® treatment on avocado fruit quality and physiological disorders when applied in the field via fertigation. Seasol® treatment positively impacted on postharvest quality after storage for 21 days at 7°C, and after ripening both at harvest, and out of cool storage. Treated fruit generally remained firmer than control fruit during both postharvest storage and ripening. Averaged over all assessments firmness was significantly higher in Seasol® treated fruit as measured by both hand pressure and skin shore hardness. Importantly treated fruit remained significantly firmer than control fruit by approximately 20 shore hardness units during storage for 21 days at 7°C. Flesh firmness among treated fruit was also higher than among control fruit after a similar ripening period at harvest and out of storage. Seasol® treatment also appeared to reduce flesh browning in avocado fruit particularly during postharvest storage, and ripening out of cool storage. At both assessments no flesh browning was observed in treated fruit whilst incidence of flesh browning in control fruit averaged 13% and 20%, respectively. Both flesh browning incidence and severity were significantly higher in control fruit after ripening out of cool storage. Treated and control fruit were of similar ripeness at this assessment thus it would appear that the prevention of flesh browning was largely due to Seasol® treatment. There was also a strong indication that Seasol® treatment could reduce the incidence and severity of stem end rot in avocados. Rot severity was significantly lower in treated fruit relative to control fruit, both after ripening at harvest, and out of cool storage. Comparison of flesh firmness and skin colour data collected during assessments on ripened fruit suggests that Seasol® treated fruit may remain greener when ripened compared to control fruit. A commercial advantage and greater consumer acceptance may result from avocado fruit that remains greener with higher visual quality during postharvest storage and ripening.

Recommendations

Based on this preliminary assessment no definitive recommendation can be made for the use of Seasol® treatment in the field to improve fruit quality. The experiment indicated that there were positive trends from Seasol® treatment relative to the untreated control and thus future studies are recommended where:

- The trial described in this report is replicated over several more seasons to confirm the positive impact of Seasol® treatment on avocado quality, and to confirm its potential to reduce physiological disorders and stem rots.
- Concurrent experiments should be conducted 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.
- Concurrent experiments should be conducted to determine the effect of Seasol® treatment on skin colour of ripened fruit, and to understand the interaction between treatment, fruit ripeness, and visual quality and skin colour, as greener skin colour in ripe fruit may be of commercial significance.

Experimental objectives

1. Investigate the effect of Seasol® fertigation on visual quality, flesh firmness and composition of avocado at harvest;
2. Determine the effect of Seasol® fertigation on 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

Fruit harvest, delivery and preparation

From ten trees used in the experiment 20 fruit per tree were randomly selected after all fruit were graded to commercial market standards. On the 3rd April 2017 one standard tray of fruit from each tree was delivered to John Lopresti in Melbourne with each tray containing Grade 25 fruit (Fig. 1). On arrival all fruit were weighed, scored for hand pressure firmness and skin colour, and then placed 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.

Figure 1. Avocados supplied for harvest and postharvest quality 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 five 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 five 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:

A. Harvest (unripened fruit)
B. Harvest + ripening for 10 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) unprotected test with statistical differences between means determined at a 5% significance level ($\alpha = 0.05$). Multiple comparisons at each assessment were conducted whether or not the overall *P*-value was significant (i.e., the comparison was unprotected). 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 plastic 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 conducted until the majority of fruit reached a hand pressure firmness score of 3 after approximately 10 days at 18°C. After postharvest storage fruit were ripened until most had reached a hand pressure score of between 4 and 5.

Fruit assessments

At each assessment the following quality attributes were measured on 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 incidence and severity of physiological disorders and flesh rots were calculated based on five fruit per tree per assessment. For severity of fruit physiological disorders, and rot severity, the severity score (SS) was calculated using the Townsend-Heuberger formula (Townsend & Heuberger, 1943):

$SS\ (\%) = \sum(dn) \div DN \times 100$; where

d = degree of infection or disorder according to severity scoring scale (e.g., 1, 2 or 3)
n = number of fruit per severity category
D = highest degree of infection or disorder possible
N = five fruit per tree per assessment

Fruit quality

Visual skin colour score

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

Figure 2. 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 3.

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 3. Hand pressure firmness rating scale.

Durometer and penetrometer 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 (Fig. 4). During firmness measurements soft spots on fruit were avoided. The firmness tester was calibrated to zero prior to measurements at each assessment.

Firmness on the flesh of ripened fruit was measured on both cheeks using an Effegi penetrometer with an 11 mm probe mounted on Firmtech FTA unit. Penetrometer and durometer measurements on each cheek were taken next to each other (Fig. 5). Penetrometer measurements were not conducted on hard fruit at harvest and after postharvest storage as the force required to penetrate hard avocado flesh was beyond the capacity of the FTA unit.

Figure 4. Skin removed from cheeks of avocados prior to flesh firmness measurements.

Figure 5. Flesh firmness measurement on ripe fruit using a Firmtech Effegi penetrometer.

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 (Fig. 6). Dried avocado cheeks were then weighed again and the dry matter concentration calculated.

Figure 6. Avocado cheeks prepared for drying and determination of DM.

External physiological disorders

Stem end browning

A four-point rating scale was used to describe stem end browning severity where 0 = none; 1 = slight; 2 = moderate; and 3 = severe browning (Fig. 7). 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.

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. 8). Half ratings were used where necessary for a more precise skin colour score (e.g., 1.5).

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. 9). Half ratings were used where necessary for a more precise scoring of skin spotting (e.g., 3.5).

Figure 7. Stem end browning rating scale (1 = left; 2 = middle; 3 = right).

Figure 8. Discrete skin patch rating scale (1 = left; 2 = middle; 3 = right).

Figure 9. Skin spotting rating scale (0 = left; 3 = middle; 5 = right).

Flesh physiological disorders

<u>Diffuse flesh browning</u>

A four-point rating scale was used to describe severity of diffuse flesh discolouration and browning not associated with flesh bruising, where 0 = none; 1 = 10% of flesh; 2 = 25% of flesh; and 3 = 50% of flesh (Fig. 10 and 11). Half ratings were used where necessary for a more precise scoring of flesh browning (e.g., 1.5).

<u>Stringy vascular flesh</u>

A four-point rating scale was used to describe severity of stringy vascular flesh where 0 = none; 1= slight; 2 = moderate; and 3 = severe (Fig. 11). Half ratings were used where necessary for a more precise scoring of flesh stringiness (e.g., 1.5).

<u>Stem end rot</u>

A four-point rating scale was used to describe stem end rot severity in fruit where 0 = none; 1 = 10% of flesh; 2 = 25% of flesh; and 3 = 50% of flesh (Fig. 12). Half ratings were used where necessary for a more precise scoring of stem end rot (e.g., 2.5).

Figure 10. Diffuse flesh discolouration rating scale.

Figure 11. Example of fruit flesh with a stringy vascular rating of 2 (left) and fruit with diffuse flesh browning.

Figure 12. Stem end rot rating scale.

Results

Fruit mass & weight loss during storage

At Day 0 no significant difference in fruit weight was found between treated and control fruit with harvested fruit having a mean weight of approximately 190 g (Table 1). As expected ripening at 18°C significantly increased weight loss in fruit compared to storage at 7°C but at each assessment there was no significant difference in weight loss among treated and control fruit.

Table 1. Treatment effect on mean fruit mass at Day 0, and fruit weight loss during cool storage and ripening.

	Fruit mass (g)	Fruit weight loss (%)		
Treatment	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	188.7 a	4.5 a	9.1 a	6.9 a
Control	191.6 a	4.4 a	8.9 a	7.2 a
Treatment *P* -value	0.570	0.982		
Assessment *P* -value		<0.001		
Treatment x Assessment *P* -value		0.793		

Flesh dry matter

At Day 0 no significant difference in flesh dry matter concentration (DM) was found between treated and control fruit with harvested fruit having an average DM concentration of approximately 26% (Table 2). There was little change in flesh dry matter among avocado fruit during storage and ripening, with no significant difference in DM due to treatment at each fruit assessment. At each assessment no significant difference in the variation of DM was observed among fruit sampling units from treated and control trees (Table 3).

Table 2. Treatment effect on mean flesh dry matter concentration during cool storage and ripening.

	Flesh dry matter (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	26.0 a	25.3 a	25.9 a	27.0 a	25.9 a
Control	26.6 a	26.2 a	26.1 a	27.3 a	26.9 a
Treatment *P* -value	0.205				
Assessment *P* -value	0.217				
Treatment x Assessment *P* -value	0.912				

Table 3. Treatment effect on coefficient of variation for flesh dry matter concentration during cool storage and ripening.

	Flesh dry matter coefficeint of variation (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	5.7 a	4.6 a	4.9 a	6.8 a	6.4 a
Control	5.4 a	5.8 a	5.2 a	4.8 a	5.8 a
Treatment *P* -value	0.611				
Assessment *P* -value	0.522				
Treatment x Assessment *P* -value	0.236				

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 hand firmness between treated and control fruit (Table 4). At both assessments after fruit ripening treated fruit remained firmer than control fruit but this difference was only statistically significant at the Day 0 + Ripe assessment, although at both assessments the treated fruit remained firmer by a similar firmness score of approximately 0.8 unit. Over all assessments hand pressure firmness score was significantly lower in treated fruit relative to control fruit.

Table 4. Treatment effect on mean hand pressure firmness score during cool storage and ripening.

	Hand pressure firmness score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	2.1 b	0 a	1.2 a	2.8 b	4.4 a
Control	2.5 a	0 a	1.5 a	3.6 a	5.1 a
Treatment *P* -value	0.012				
Assessment *P* -value	<0.001				
Treatment x Assessment *P* -value	0.351				

At Day 0 mean shore hardness score measured on fruit skin was 100 in both treated and control fruit whilst fruit softened marginally during storage for 21 days at 7°C, with treated fruit remaining significantly firmer than control fruit (Table 5). Treated fruit were also significantly firmer than control fruit by 5 to 6 shore hardness units after ripening at Day 0, and after 3 weeks of postharvest storage. Over all assessments fruit firmness as measured on the skin was significantly higher in treated fruit relative to control fruit.

Table 5. Treatment effect on fruit skin shore hardness score during cool storage and ripening.

	Skin shore hardness score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	91.0 b	100 a	96.3 b	80.2 b	87.6 b
Control	87.4 a	100 a	92.8 a	74.2 a	82.7 a
Treatment *P* -value	<0.001				
Assessment *P* -value	<0.001				
Treatment x Assessment *P* -value	0.080				

At Day 0 mean shore hardness score measured on fruit flesh was not significantly different among treated and untreated fruit but after storage for 21 days at 7°C treated fruit had significantly firmer flesh than untreated fruit (Table 6). Similarly flesh in treated fruit remained significantly firmer than in control fruit after ripening at Day 0. After 3 weeks of postharvest storage and ripening treated fruit were 10 shore hardness units firmer than treated fruit but this difference was not significant due to relatively large variability among fruit within treated trees. Over all assessments flesh firmness as measured by shore hardness score was significantly higher in treated fruit relative to control fruit.

Table 6. Treatment effect on fruit flesh shore hardness score during cool storage and ripening.

	Flesh shore hardness score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	56.9 b	98.1 a	84.0 b	29.6 b	15.9 a
Control	44.9 a	97.8 a	62.8 a	13.6 a	5.4 a
Treatment *P* -value	<0.001				
Assessment *P* -value	<0.001				
Treatment x Assessment *P* -value	0.101				

The results obtained for fruit flesh firmness using shore hardness score were confirmed for ripened fruit by Effegi penetrometer measurements (Table 7). Flesh of treated fruit remained significantly firmer than in control fruit after ripening at Day 0. After 3 weeks of postharvest storage and ripening there was no significant difference in flesh firmness measured with a penetrometer among treated and untreated fruit.

Table 7. Treatment effect on fruit Effegi penetrometer firmness during ripening.

	Effegi penetrometer firmness (kgf)		
Treatment	**Overall**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.21 b	1.44 b	0.99 a
Control	0.90 a	0.94 a	0.85 a
Treatment *P* -value	0.006		
Assessment *P* -value	0.014		
Treatment x Assessment *P* -value	0.086		

The strong positive correlation between hand pressure firmness score and flesh shore hardness score indicates that hand pressure can be used as a good indicator of avocado ripeness (Fig. 13). Of course the strength of this correlation is likely to vary depending on the experience of the person conducting hand pressure measurements. Scores from both treated and untreated fruit were combined in determining the relationship between the two firmness measurements.

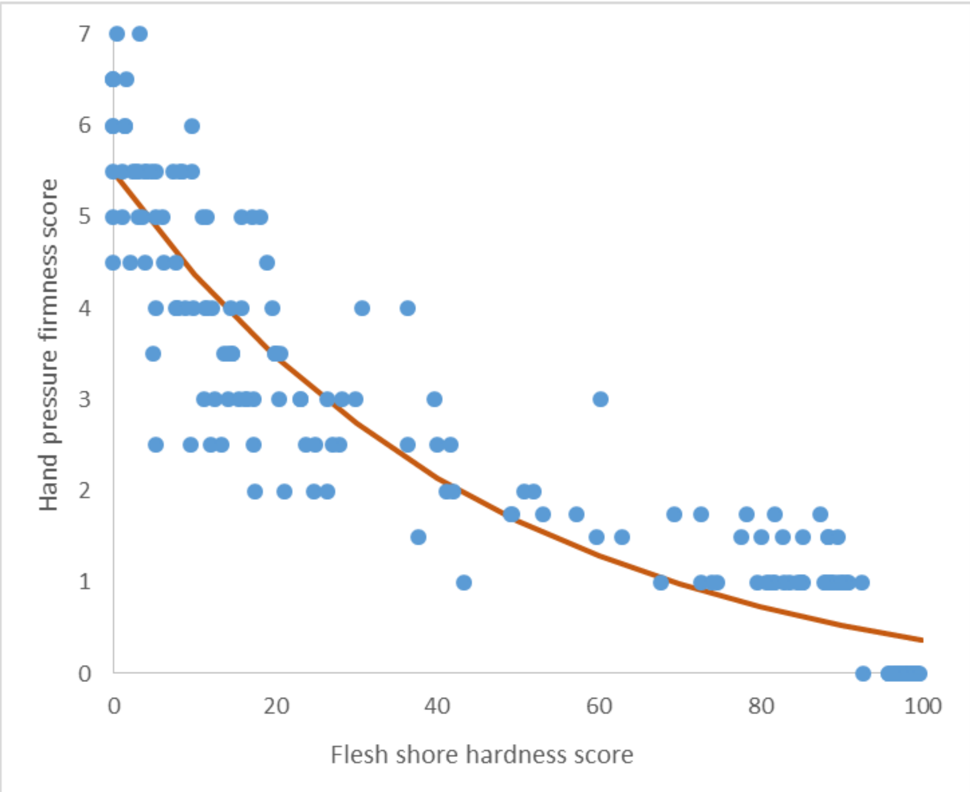

Figure 13. Correlation between hand pressure firmness score and flesh shore hardness score for avocado fruit during postharvest storage and ripening ($r^2 = 0.88$, $P < 0.001$, $SE_{obs} = 0.71$, $N = 200$).

Fruit skin colour

At Day 0 mean skin colour was 1.0 among both treated and untreated fruit based on visual scoring but after storage for 21 days at 7°C treated fruit was significantly greener than untreated fruit (Table 8). In ripened fruit after Day 0 and after 3 weeks of postharvest storage there was no significant difference in skin colour but control fruit were marginally darker than treated fruit. Over all assessments skin colour as measured by visual scoring was significantly higher in control fruit relative to treated fruit.

Table 8. Treatment effect on fruit skin colour score during cool storage and ripening.

	Skin colour score				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.7 b	1.0 a	1.1 b	2.3 a	2.4 a
Control	2.0 a	1.0 a	1.6 a	2.6 a	2.8 a
Treatment *P*-value	0.024				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.495				

At Day 0 mean skin colour as measured by hue angle was similar among treated and untreated fruit and also did not differ significantly after postharvest storage for 21 days at 7°C (Table 9). At Day 0 and after 3 weeks of postharvest storage ripened treated fruit remained greener than control fruit, although the difference in hue angle was only significantly higher in fruit ripened after postharvest storage. Over all assessments skin colour as measured by hue angle was significantly higher in treated fruit relative to control fruit.

Table 9. Treatment effect on fruit skin colour during cool storage and ripening as measured via hue angle.

	Skin hue (°)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	122.2 b	123.5 a	121.5 a	121.7 a	122.1 b
Control	120.9 a	123.0 a	120.5 a	120.1 a	120.2 a
Treatment *P*-value	0.005				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	0.695				

Overall, and at all fruit assessments, no significant difference in skin lightness was found among treated and untreated fruit with all fruit darkening similarly after ripening (Table 10). It should be noted that skin hue angle and lightness were point measurements on fruit and that they may not be representative of the colour or degree of darkening across a whole fruit.

Table 10. Treatment effect on fruit skin lightness (*L*) value during cool storage and ripening.

	Skin lightness (*L*) value				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	33.9 a	33.8 a	31.8 a	34.6 a	35.5 a
Control	33.7 a	33.8 a	31.7 a	34.0 a	35.4 a
Treatment *P* -value	0.529				
Assessment *P* -value	<0.001				
Treatment x Assessment *P* -value	0.925				

Fruit external physiological disorders

After postharvest storage for 21 days at 7°C, and ripening for 3 days at 18°C, overall fruit visual quality was generally higher among treated fruit (Tree 1 to 5) than among control fruit (Tree 6 to 10) (Fig. 14). Although stem end browning incidence was more apparent in control fruit at Day 0, particularly at Day 0 after ripening, at both assessments no significant difference in incidence was observed among treated and control fruit (Table 11). No stem end browning was observed on fruit stored for 21 days, and after subsequent ripening. At Day 0 + Ripening stem end browning severity was significantly higher in control fruit relative to treated fruit, with no difference between treated and control fruit observed at Day 0 (Table 12).

No skin discrete patches were observed among treated and untreated fruit at Day 0, Day 0 + Ripening, and after postharvest storage (Day 21), thus the overall *P*-value across assessments was not significant. But at Day 21 + Ripening mean incidence of discrete patches was 20% higher among control fruit relative to treated fruit (Table 13). Skin discrete patch severity at Day 21 + Ripening was also 16% higher among control fruit, but again the overall *P*-value across assessments was not significant (Table 14).

Seasol® treatment had no significant effect on incidence of fruit with skin spot (Table 15), or severity of skin spot on fruit (Table 16), relative to control fruit, with skin spot only observed among treated and control fruit at Day 21 + Ripening.

Figure 14. Avocado visual quality after postharvest storage for 21 days at 7°C, and ripening for 3 days at 18°C (Tree 1 at top through to Tree 10 at bottom).

Table 11. Treatment effect on incidence of fruit stem end browning during cool storage and ripening.

	Stem browning incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.0 a	0 a	0 a	4.0 a	0 a
Control	4.7 a	4.0 a	0 a	14.6 a	0 a
Treatment *P* -value	0.098				
Assessment *P* -value	0.012				
Treatment x Assessment *P* -value	0.270				

Table 12. Treatment effect on severity of fruit stem browning during cool storage and ripening.

	Stem browning severity (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	0.3 b	0 a	0 a	1.3 b	0 a
Control	2.6 a	1.3 a	0 a	8.9 a	0 a
Treatment *P* -value	0.049				
Assessment *P* -value	0.005				
Treatment x Assessment *P* -value	0.058				

Table 13. Treatment effect on incidence of skin discrete patch during cool storage and ripening.

	Skin discrete patch incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.0 a	0 a	0 a	0 a	5.0 b
Control	6.0 a	0 a	0 a	0 a	25.0 a
Treatment *P* -value	0.198				
Assessment *P* -value	0.030				
Treatment x Assessment *P* -value	0.182				

Table 14. Treatment effect on severity of skin discrete patch during cool storage and ripening.

	Skin discrete patch severity (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	0.3 a	0 a	0 a	0 a	1.3 b
Control	4.3 a	0 a	0 a	0 a	17.3 a
Treatment *P* -value	0.115				
Assessment *P* -value	0.025				
Treatment x Assessment *P* -value	0.068				

Table 15. Treatment effect on incidence of skin spot during cool storage and ripening.

	Skin spot incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	15.0 a	0 a	0 a	0 a	57.0 a
Control	14.0 a	0 a	0 a	0 a	53.0 a
Treatment *P* -value	0.813				
Assessment *P* -value	<0.001				
Treatment x Assessment *P* -value	0.982				

Table 16. Treatment effect on severity of skin spot during cool storage and ripening.

	Skin spot severity (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	7.7 a	0 a	0 a	0 a	27.7 a
Control	7.7 a	0 a	0 a	0 a	27.7 a
Treatment *P* -value	1.000				
Assessment *P* -value	<0.001				
Treatment x Assessment *P* -value	1.000				

Flesh physiological disorders

No flesh stringiness was observed among treated and control fruit at Day 0, and after ripening. At both Day 21, and Day 21 + Ripening, control fruit had higher flesh stringiness incidence than treated fruit, by 10% and 8% respectively, but these differences were not statistically significant (Table 17). Severity of flesh stringiness was also higher in control fruit relative to treated fruit at both Day 21 assessments but again these differences were not statistically significant (Table 18).

Table 17. Treatment effect on incidence of flesh stringiness during cool storage and ripening.

	Flesh stringiness incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.0 a	0 a	0 a	0 a	4.0 a
Control	5.7 a	0 a	10.6 a	0 a	12.0 a
Treatment *P* -value	0.108				
Assessment *P* -value	0.131				
Treatment x Assessment *P* -value	0.429				

Table 18. Treatment effect on severity of flesh stringiness during cool storage and ripening.

	Flesh stringiness severity (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	0.3 a	0 a	0 a	0 a	1.3 a
Control	2.2 a	0 a	3.6 a	0 a	5.3 a
Treatment *P* -value	0.118				
Assessment *P* -value	0.154				
Treatment x Assessment *P* -value	0.469				

At both Day 21, and Day 21 + Ripening, control fruit had higher flesh browning incidence than treated fruit, by 13% and 20% respectively, with no flesh browning observed on treated fruit, and overall *P*-value across assessments not significant (Table 19). But at Day 21 + Ripening flesh browning incidence and severity among control fruit was significantly higher than in treated fruit (Table 20). No flesh browning was observed among treated and control fruit at Day 0, but after ripening, both incidence and severity of flesh browning were marginally higher in control fruit but not significantly higher relative to treated fruit.

Table 19. Treatment effect on incidence of flesh browning during cool storage and ripening.

	Flesh browning incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.0 a	0 a	0 a	0 a	0 b
Control	8.3 a	0 a	13.2 a	4.0 a	20.0 a
Treatment *P*-value	0.085				
Assessment *P*-value	0.324				
Treatment x Assessment *P*-value	0.156				

Table 20. Treatment effect on severity of flesh browning during cool storage and ripening.

	Flesh browning severity (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	0 a	0 a	0 a	0 a	0 b
Control	3.7 a	0 a	6.7 a	1.3 a	8.0 a
Treatment *P*-value	0.098				
Assessment *P*-value	0.403				
Treatment x Assessment *P*-value	0.251				

No stem end rot was observed among treated and control fruit at Day 0 and Day 21 assessments. After ripening at both Day 0 and Day 21, control fruit had higher stem end rot incidence than treated fruit, by 8% and 12%, respectively, with the difference being only statistically significant at Day 21 + Ripening (Table 21). Severity of stem end rot after ripening was significantly higher in control fruit relative to treated fruit at both Day 0 and Day 21 assessments (Table 22). Over all assessments incidence and severity of stem end rot was significantly higher among control fruit relative to treated fruit.

Table 21. Treatment effect on incidence of stem end rot during cool storage and ripening.

	Stem rot incidence (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	1.0 b	0 a	0 a	4.0 a	0 b
Control	6.0 a	0 a	0 a	12.0 a	12.0 a
Treatment *P* -value	0.018				
Assessment *P* -value	0.012				
Treatment x Assessment *P* -value	0.101				

Table 22. Treatment effect on severity of stem end rot during cool storage and ripening.

	Stem rot severity (%)				
Treatment	**Overall**	**Day 0**	**Day 21**	**D0 + Ripe**	**Day 21 + Ripe**
Seasol	0.3 b	0 a	0 a	1.3 b	0 b
Control	3.7 a	0 a	0 a	6.7 a	8.0 a
Treatment *P* -value	0.007				
Assessment *P* -value	0.016				
Treatment x Assessment *P* -value	0.045				

Discussion & Conclusions

Avocado quality

Previous studies have demonstrated that seaweed extracts applied to fruit can positively impact on postharvest fruit quality (Lopresti et al., 2016). Keeping in mind the experimental limitations of this preliminary assessment, the field application of Seasol® to avocado fruit via fertigation positively impacted on postharvest quality after storage for 21 days at 7°C, and after ripening both at harvest and out of cool storage.

Fruit firmness averaged over all assessments was significantly higher in Seasol® treated fruit as measured by both hand pressure and skin shore hardness. These differences in fruit firmness were most apparent after fruit were ripened for 10 days at harvest, and for three days out of storage. Flesh firmness averaged over all assessments was also significantly higher in Seasol® treated fruit as measured by flesh shore hardness and Effegi penetrometer (on ripened fruit). Importantly treated fruit remained significantly firmer than control fruit by approximately 20 shore hardness units during storage for 21 days at 7°C. Flesh firmness among treated fruit was also higher than among control fruit after a similar ripening period at harvest and out of storage. The potential effect of Seasol® treatment in limiting firmness loss among fruit during cool storage may be of commercial importance if harvested fruit requires storage prior to marketing.

Fruit skin colour averaged over all assessments was significantly higher in Seasol® treated fruit as measured by both visual colour scoring and hue angle. These differences in skin colour were most apparent out of storage based on visual scoring, and after ripening out of storage based on hue angle. It should be noted that at each assessment mean differences in skin colour were marginal and not likely to be commercially significant. In this experiment Seasol® treatment did not significantly increase dry matter (DM) concentration in avocado flesh at harvest, or during storage and ripening, relative to DM in 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. No significant difference in mean harvest weight was found between treated and untreated fruit, whilst fruit weight loss during postharvest storage and ripening was similar among all fruit.

Avocado physiological disorders

Differences in external physiological skin disorders due to Seasol® treatment were less apparent than those observed for fruit quality. Seasol® treatment appeared to reduce incidence and severity of stem end browning after ripening at harvest, and incidence and severity of discrete patches on skin after ripening out of storage, relative to control fruit. But for both disorders, symptoms were only apparent among fruit from several control trees resulting in high variation among control trees and thus lack of treatment statistical significance. The potential effect of Seasol® treatment on fruit visual quality after ripening requires further assessment as results in this trial suggest that after ripening out of storage incidence and severity of discrete patches was approximately 20% and 16% lower, respectively, compared to control fruit.

Seasol® treatment also appeared to reduce flesh browning in avocado fruit particularly during postharvest storage, and ripening out of cool storage. At both assessments no flesh browning was observed in treated fruit whilst incidence of flesh browning in control fruit averaged 13% and 20% respectively. Both flesh browning incidence and severity were significantly higher in control fruit after ripening out of cool storage. Treated and control fruit were of similar ripeness at this assessment thus it would appear that the prevention of flesh browning was largely due to Seasol® treatment. Flesh browning is a commercially-important physiological disorder in avocado particularly when fruit is ripened after being stored at temperatures that may cause chilling injury. The effect of Seasol® treatment in reducing or preventing flesh browning should be explored further and its interaction with storage temperature and storage period also determined.

In this trial there were strong indications that Seasol® treatment may have the potential to reduce the incidence and severity of stem end rot in avocados that was observed at both ripening assessments. Rot severity was significantly lower in treated fruit relative to control fruit, both after ripening at harvest, and out of cool storage. Again this result appeared to be independent of fruit ripeness and could indicate that treatment inhibits rot development. The potential for Seasol® treatment to reduce stem end rot in ripened fruit, and other external and internal rots, should be explored further.

Avocado colour and ripeness

Comparison of flesh firmness and skin colour data collected during assessments on ripened fruit suggests that Seasol® treated fruit may remain marginally greener when ripened compared to control fruit. For example after ripening out of storage, although there was no significant difference in flesh shore hardness score, skin colour was significantly greener in treated fruit relative to control fruit based on skin hue angle. A commercial advantage and greater consumer acceptance may result from avocado fruit that remains greener with higher visual quality during postharvest storage and ripening. A similar positive interaction between high fruit colour and firmer fruit due to Seasol® treatment was observed in experiments on strawberry fruit (Lopresti et al. 2016). The potential interaction between Seasol® treatment, fruit ripeness, and visual quality and skin colour, should be explored further as greener skin colour in ripe fruit may be of commercial significance.

References

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