RESEARCH TOWARDS REDUCING ORCHARD COLD DAMAGE OF 'HASS' AVOCADO FRUIT

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ABSTRACT

Products applied as foliar sprays have been effective towards reducing freeze damage in annual as well as tree crops. The need existed to test the efficacy of these products on avocados. The objective of this project was to determine the efficacy of the combination foliar application of two AECI products, Alexin and Rappid K, in an attempt to increase the cold hardiness of 'Hass' avocado fruit. AECI Plant Health indicates that these products are used effectively in different annual crops (vegetables) as protective measures against freeze damage in South Africa. Alexin contains salicylic acid which is known to improve freezing tolerance of several commodities. On 14 May 2021 an appropriate high nitrogen 'Hass' orchard (leaf N = 2.4%) prone to developing orchard cold damage, Westfalia Werne farm, orchard 15, was identified. The thick wax layer on the leaves and fruits of avocados evidently inhibits the effective absorption of Ca and B and other nutrients. Hence, two additional treatments including adjuvants with penetrating properties, namely PANAF 5 (contains lipid-amino acid) as well as WetCit (a very effective wetter with penetrating properties) were tested for improved absorption through the wax layer barrier. The first significant cold event of -1.5 °C occurred on 23 July 2021, 5 days after the third foliar application of Alexin and Rappid K. As count 20 fruits with no visible skin damage are prone to show pulp cold damage, 100 fruits (count 20, 20 fruits per tree) were randomly selected from the harvest crates for each treatment. The untreated control (UTC) and the Alexin + WetCit treatments exhibited the lowest TSS values (14.6 and 14.2 °Brix, respectively). This indicates that the inclusion of WetCit as a wetter/penetrator possibly inhibited the absorption of salicylic acid for an unknown reason. The fruits harvested with visible fruit skin orchard cold damage from the UTC treatment trees exhibited the highest incidence of internal pulp orchard cold damage (80.9%). This included mostly Scale 2 severity values for the specific disorder. Count 20 fruits harvested without visible fruit skin orchard cold damage from the UTC treatment trees exhibited a lower incidence of internal pulp orchard cold damage (41.8%). This included only Scale 1 severity value for the specific disorder. The leaf sap TSS values of Alexin with no wetter and the Alexin + PANAF 5 treatments increased to 15 and 15.5 °Brix, respectively. The higher TSS of these two Alexin treatments compared to the UTC treatment at 14.6 °C most likely illustrates the efficacy of salicylic acid in increasing the TSS content in avocados. Similar results were also obtained for fruit pulp TSS. The former two treatments also resulted in less fruit with visible orchard cold damage on the skin, compared to the untreated control. The fruit harvested with visible fruit skin orchard cold damage from the Alexin treatment with no wetter/penetrator applied, exhibited an incidence of 21.1% internal pulp orchard cold damage, whereas fruit without visible orchard cold damage exhibited no internal pulp orchard cold damage. The fruit harvested with and without visible fruit skin orchard cold damage from the Alexin + PANAF 5 treated trees exhibited no internal pulp orchard cold damage, indicating this combination's possible use in improving cold hardiness and that PANAF 5 is a good wetter/penetrator to improve penetration of the product into the fruits and leaves of avocados during foliar sprays.

BACKGROUND

When air temperatures fall below 0 °C, sensitive crops can be injured with significant effects on production. For example, in the USA, there are more economic losses due to frost damage than any other weather-related phenomenon (White and Haas, 1975). Technically, the word "frost" refers to the formation of ice crystals on surfaces, either by freezing of dew or a phase change from vapour to ice (Cunha, 1982). However, the word is widely used by the public to describe a meteorological event when crops and other plants experience freezing injury. Growers often use the terms "frost" and "freeze" interchangeably, with the vague definition being "an air temperature less than or equal to 0 °C".

Snyder and Connell (1993) and Kalma *et al.,* (1992) have defined frost as falling into two categories: "advective" and "radiative". Advective frost is associated with large-scale incursions of cold air with a well-mixed, windy atmosphere and a temperature that is often sub-zero, even during the daytime. Radiative frost is associated with cooling due to energy loss through radiant exchange during clear, calm nights, and with temperature inversions (i.e. temperature increases with height). In some cases, a combination of both advective and radiative conditions will occur. For example, it is not uncommon to have advective conditions bringing a cold air mass into a region, resulting in an advection frost. This may be followed by several days of clear, calm conditions that are conducive to radiation frost. In addition, the authors have observed conditions that are considered as "micro-scale advection frost". These occur when the region is exposed to radiation-type frost conditions, but local cold air drainage leads to rapid declines in temperature on a small scale within the radiation frost area.

A "frost" is the occurrence of an air temperature of 0 °C or lower, measured at a height of between 1.25 and 2.0 m above soil level, inside an appropriate weather shelter. Water within plants may or may not freeze during a frost event, depending on several avoidance factors (e.g. super-cooling and concentration of ice-nucleating bacteria). A "freeze" occurs when extracellular water within the plant freezes (i.e. changes from liquid to ice). This may or may not lead to damage of the plant tissue, depending on tolerance factors (e.g. solute content of the cells). A frost event becomes a freeze event when extracellular ice forms inside of the plants. Freeze injury occurs when the plant tissue temperature falls below a critical value where there is an irreversible physiological condition that is conducive to death or malfunction of the plant cells. This damaging plant tissue temperature is correlated with air temperatures called "critical temperatures", measured in standard instrument shelters. Sub-zero air temperatures are caused by reductions in the sensible heat content of the air near the surface, mainly resulting from (1) a net energy loss through radiation from the surface to the sky (i.e. radiation frost); (2) wind blowing in sub-zero air to replace warmer air (i.e. advection frost); or (3) some combination of the two processes.

Radiation frost is a common occurrence. It is characterised by a clear sky, calm or very little wind, temperature inversion, low dew point temperature and air temperature that typically fall below 0 °C during the night but are above 0 °C during the day. The dew point temperature is the temperature reached when the air is cooled until it reaches 100% relative humidity, and is a direct measure of the water vapour content of the air. Under clear night time skies, more heat is radiated away from the surface than is received, so the temperature drops. The temperature falls faster near the radiating surface, causing a temperature inversion to form (i.e. temperature increases with height above the ground). As there is a net loss of energy through radiation from the surface, the sensible heat content of the soil surface and air near the surface decreases. There is a flux of sensible heat downward from the air and upward from within the soil to the surface to replace the lost sensible heat. This causes the temperature to decrease aloft as well, but not as rapidly, as at the surface. The depth to the top of the temperature inversion is variable depending on local topography and weather conditions, but generally ranges from 9 to 60 m (Perry, 1994).

Advection frost occurs when cold air blows into an area to replace warmer air that was present before the weather change. It is associated with cloudy conditions, moderate to strong winds, no temperature inversion and low humidity. Often temperatures will drop below the melting point (0 °C) and will stay there all day. Because many of the active protection methods work better in the presence of an inversion, advection frost is difficult to combat. In many cases, a series of sub-zero nights will start as an advection frost and will later change to radiation frost nights. For deciduous fruit and nut trees, damaging frost events occur mainly in spring, but sometimes in autumn as well. For subtropical fruits, damage to the crops typically occurs during winter.

In recent years, preharvest cold damage/orchard cold damage of avocado fruits has become a significant problem, particularly in the Tzaneen area, Limpopo. Preharvest cold damage has occurred in low-lying areas and orchards with poor air drainage, rendering all the fruit from those orchards unfit for market, resulting in significant financial loss.

Methods assisting towards improved cold hardiness

Plant nutrition management

Unhealthy trees are more susceptible to frost damage, and fertilization improves plant health in this case. Also, trees that are not properly fertilized tend to lose their leaves earlier in autumn and bloom earlier in spring, which increases susceptibility to frost damage. However, the relationship between specific nutrients and increased resistance to frost damage is obscure, and the literature contains many contradictions and partial interpretations. In general, nitrogen and phosphorus fertilization before a frost encourage growth and increase susceptibility to frost damage. To enhance the hardening of plants, avoid applications of nitrogen fertilizer in late summer or early autumn. It has been shown that orchards with low nitrogen were more prone to develop orchard cold damage (Kruger *et al*., 2008), so the time of application is crucial to maintain optimum nitrogen levels. Phosphorus is also important for cell division and therefore is important for recovery of tissues after freezing, and so optimum soil phosphorus is desirable. Potassium has a favourable effect on water regulation and photosynthesis, drought tolerance, improved winter hardiness and protein synthesis in plants.

Cold stress can also be addressed with silicon. South African scientists working with bananas have shown that silicon protected the plants from cold damage (Kidane, 2008). Calcium (Ca), boron (B) and silicon (Si) are synergists and together represent proactive cell strengthening that will protect a plant during any stress condition. Two minerals that can effectively create a protective barrier (a strong cell wall) are calcium and silica and both of these need boosting in most crops. Boron is also integrated into the cell membrane to strengthen it.

Irrigation

When soils are dry there are more air spaces, which inhibit heat transfer and storage. Therefore, in dry years frost protection is improved by wetting dry soils. The goal is to maintain the soil water content near field capacity, which is typically the water content 1 to 3 days following thorough wetting. It is unnecessary to wet the soil deeply because most of the daily heat-transfer and storage occurs in the top 30 cm. Wetting the soil will often make it darker and increases the absorption of solar radiation. However, when the surface is wet, then evaporation is also increased and the energy losses to evaporation tend to counterbalance the benefits from better radiation absorption. It is best to wet dry soils well in advance of a frost event so that the sun can warm the soil.

Bacteria control

Ice nucleation active (INA) bacteria are a group of bacteria with the ability to catalyse ice formation at a temperature above -10 °C and cause frost injury in plants. For freezing to occur, the ice formation process is mostly initiated by the presence of INA bacteria. The higher the concentration of the INA bacteria, the more likely that ice will form. After forming, these propagate inside the plants through openings on the surface into the plant tissue. Commonly, pesticides (copper compounds) are used to kill the bacteria. Two distinct bacteria capable of freezing nucleus activity at temperatures as warm as -2.5 °C were repeatedly isolated from citrus and avocado plants in Israel (Saul *et al*., 1981).

Increased TSS is related to increased cold hardiness

Plant cells undergo dehydration during freezing stress due to the presence of ice in extracellular spaces (Levit, 1980). Membrane damage is mainly due to the dehydration that occurs during the freeze-thaw cycle.

Freezing-induced destabilisation of the plasma membrane involves different types of lesions. Increases in total soluble solids (TSS) ameliorate the impact of dehydration associated with freezing (Tomashow, 1999). It has been reported that cold acclimation is accompanied by biochemical changes, including the expression of cold-shock proteins (such as dehydrins) and the accumulation of sugars, particularly sucrose and sugar alcohols (mannitol and inositol) (Stit and Hurry, 2002).

Physiologically, compatible solutes should have no adverse metabolic effects, even at very high concentrations. They are thought to stabilise sensitive cellular components under stress conditions and act as bulk osmo-protectants. This demonstrates the importance of increasing plant TSS to increase its cold tolerance, preferably prior to expected cold periods.

Salicylic acid (SA) is a natural phenolic compound involved in regulation of many processes in plant growth and development. SA is also known for its induction of plant defence against biotic and abiotic stress and is reported to increase chilling tolerance in peach (Wang *et al*., 2006), tomato (Ding *et al*., 2002) and sweet peppers (Fung *et al*., 2004). Salicylic acid also increases TSS in several commodities.

OBJECTIVE

To determine the efficacy of foliar applications of two AECI Plant Health products (Alexin and Rappid K) in an attempt to increase the cold hardiness of 'Hass' avocado fruits:

- Alexin contains SA, known to improve freezing tolerance of several commodities.
- Both Alexin and Rappid K have been effectively applied in annual vegetable crops in South Africa to reduce freezing damage, which justified testing on avocado.

MATERIALS AND METHODS

Trial site

On 14 May 2021 an appropriate 'Hass' orchard prone to developing orchard cold damage (Westfalia, Werne farm, orchard 15) was identified. The orchard is situated on a ridge, and at the lower part of the orchard cold air can accumulate.

Nutrient correction spray

To determine if nutrient deficiencies occur, leaf samples (young and mature leaves) were taken on 18 May for leaf sap nutrient analyses. Leaf sap nutrient analyses indicated that N, P, K, Ca and Fe deficiencies were present in the trees of the trial plot.

To address these deficiencies, a correction spray of AECI Plant Health products, namely Rappid (N, P, 500 ml/100 L), Fruitboost phase 2 (Ca, K, Zn, B, 500 ml/100 L) and Ferromax (Fe, 200 ml/100 L) were applied on 2 June.

Foliar applications to improve cold hardiness

The combination spray of Alexin and Rappid K needs to be applied at least 7 days prior to an expected cold event. As temperatures below 0 ºC were expected on this farm during early to late July, it was decided to spray in a preventative manner. One spray provides 4 weeks of protection. It needs to be applied on a 3 weekly basis to provide continual protection during a certain time period.

- 1st Foliar spray
  A foliar application of Alexin (2 ℓ/ha) and Rappid K (potassium-poli-phosphate 7.5 ℓ/ha) as well as CungFu 538 SC (2.0 ℓ/ha, to control INA bacteria that form the nucleus around which ice crystals develop) were applied on 7 June.

- 2nd Foliar spray
  As the temperature did not drop below 3 °C in the 21 day period after the 1st spray, a 2nd foliar application of Alexin (2 ℓ/ha) and Rappid K

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HALLS IS A MEMBER OF THE HL HALL & SONS GROUP (potassium-poli-phosphate 7.5 ℓ/ha) was applied on 28 June to prolong the period of protection, while waiting for an event where the temperature dropped below 0 °C.

- 3rd Foliar spray
  Three weeks later, on 19 July, the 3rd foliar application of Alexin (2 ℓ/ha) and Rappid K (potassium-poli-phosphate 7.5 ℓ/ha) was applied.

The first cold event of -1.5 °C occurred on 23 July, 5 days after the 3rd application. Two days later a Rappid K application was applied as energy source to increase the photosynthetic output.

Trial treatments
As the thick wax layer on the leaves and fruits of avocado evidently inhibits the effective absorption of nutrients, two additional treatments including two adjuvants with penetrating properties were included to assist in possible improved absorption through the wax layer barrier:
- PANAF 5 (1 ℓ/h) consists of a lipid-amino acid that is known to increase the absorption of fungicides.
- WetCit (70 mℓ/100 L) is a very effective wetter with penetrating properties. In avocados the use of this wetter can cause leaf drop. It is therefore wise to not use the maximum dosage rate, and to only spray in the early morning or late afternoon as the use of this wetter may enhance leaf drop in avocados when applied at high temperature conditions.

The trial treatments included 20 trees:
- T1 = 5 trees with no foliar applications as an untreated control (UTC).
- T2 = 5 trees with foliar applications (Alexin and Rappid K) to assist with cold hardiness without any wetter/penetrator applied.
- T3 = 5 trees with foliar applications (Alexin and Rappid K) to assist with cold hardiness, including WetCit applied as wetter/penetrator.
- T4 = 5 trees with foliar applications (Alexin and Rappid K) to assist with cold hardiness, including PANAF 5 applied as wetter/penetrator.

Evaluation criteria
As the Alexin and Rappid K treatments contain K, P, Ca, B and Mg as well as SA (which increased TSS in other crops):
- Leaf sap nutrient and TSS analyses of leaf samples were conducted to verify the efficacy of the foliar applications, by including these parameters.
- Additional to leaf sap analyses, the fruit pulp TSS was also determined:
  - 4 fruit per tree replicate (count 20 fruit; 20 fruit per treatment) were sampled for analyses 3 days after the cold event.

Ten days after the cold event, fruit exhibiting external symptoms of orchard cold damage (OCD) on the fruit skin, dropped from the trees:
- The fruit were collected to be evaluated for OCD (Scale 0-3); this included:
  - the external skin OCD and
  - internal fruit pulp OCD (fruit were cross sectioned).

The fruit were harvested 13 days after the cold event:
- The fruit with external skin OCD were removed from the picking crates of each tree replicate for all treatments, to be evaluated for:
  - fruit skin OCD (Scale 0-3) and
  - cross sectioned and evaluated for fruit pulp orchard damage symptoms (Scale 0-3).
- Count 20 fruit without external OCD present are more sensitive to internal fruit pulp OCD and hence this count was sampled. These smaller fruit may exhibit no external damage but the internal pulp symptoms of the disorder can be quite severe. Packhouses indicated that lighter green fruit are more prone to show internal fruit pulp OCD and care was taken to choose these fruit.
  - For each treatment, 20 count 20 fruit were removed from the picking crates of each tree replicate with no external OCD visible, to be:
    - cross-sectioned and evaluated for fruit pulp orchard damage symptoms (Scale 0-3).

Statistical detail
Data were analysed using One-way ANOVA (LSD test, $P < 0.05$).

RESULTS AND DISCUSSION
The first significant cold event of -1.5 °C occurred on 23 July, 5 days after the 3rd foliar application of Alexin and Rappid K. The first fruit skin colour changes associated with OCD occurred 4 days after the cold episode. On day 10, some of the fruit with visible cold damage on the fruit skin (Table 1, 22 fruit) dropped from the untreated control trees [T1], although only from 2 of the 5 replicate trees. The skin and pulp of the dropped fruit exhibited mostly severe OCD (Fig. 1). Furthermore, the total number of OCD fruits (41), which include fruit with skin OCD that dropped as well as those with skin OCD that remained on the trees, was higher for the untreated control [T1] compared to the three Alexin and Rappid K applications [T2], [T3] and [T4] (15, 17 and 12, respectively). None of the fruit exhibiting symptoms of OCD on the fruit skin of the trees treated with the three Alexin and Rappid K applications [T2], [T3] and [T4] dropped from the trees (Table 1).

Table 1: Foliar sprays to improve cold hardiness. The number of fruit per treatment, with skin OCD that dropped from the trees within 10 days after the cold period, as well as those with skin OCD sampled from the trees at harvest

No. of fruit with skin OCD:				
	T1	T2	T3	T4
Dropped from trees	22	0	0	0
Sampled at harvest from trees	21	15	17	12
Total no. of OCD fruit	41	15	17	12

This finding already to some extent indicated the efficacy of the products.

At harvest, the total fruit with visible skin cold damage were removed from the picking crates of all treatments to be evaluated separately. 21 fruit with fruit skin OCD were obtained from the untreated control [T1]. From the three Alexin + Rappid K treatments ([T2], [T3] and [T4]), 15, 17 and 12 fruit with skin OCD (Fig. 2) were obtained respectively. Varying between 1.8 and 2.29, the average skin OCD (Scale 1-3) values did not differ significantly ($P < 0.51$). However, the untreated control [T1] obtained 85.8% Scale 3 and 2 OCD values, compared to the Alexin + Rappid K treatments [T2], [T2] and [T3] that exhibited 66.7%, 76.5% and 58.3% respectively. The low percentage of severity of the disorder indicates improved cold hardiness.

The average fruit pulp OCD (Scale 0-3) harvested with visible fruit skin orchard cold damage (Fig. 3) of the UTC [T1] was significantly higher (1.62) when compared to the three Alexin + Rappid K treatments [T2], [T3] and [T4]. The UTC included mostly Scale 2 severity values for the specific disorder (80.9%). The 3 Alexin + Rappid K treatments [T2], [T3] and [T4] resulted in 0.17, 0.38 and 0 pulp OCD values (Scale 0, 1, 2 and 3) respectively, including only low Scale 1 severity values of the disorder for [T2] and [T3] (20 and 41% respectively). This suggests an improvement towards cold hardiness. The inclusion of PANAF 5 as adjuvant increased the cold hardiness further with no pulp OCD present.

Figure 1: The visual appearance of dropped 'Hass' avocado fruit with external and internal orchard cold damage.

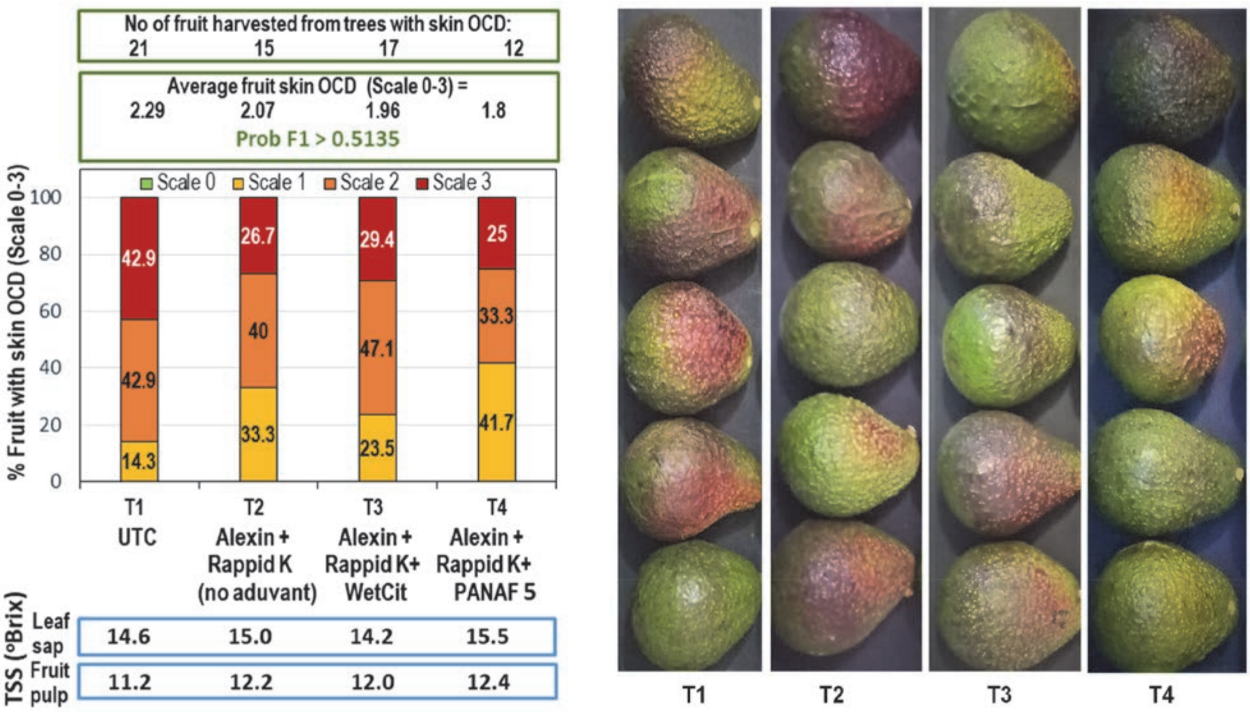

Figure 2: Foliar sprays to improve cold hardiness. The average fruit skin orchard cold damage (OCD, Scale 0-3) of fruit that remained on the tree, for samples procured from a high nitrogen 'Hass' avocado orchard that is prone to develop OCD. The number of fruit that was harvested with skin OCD per treatment, as well as the leaf sap and fruit pulp TSS values determined for leaf and fruit samples that were taken 2 days after the -1.5 °C cold event, are indicated. Stats: ANOVA; Fisher LSD ($P < 0.05$). The photographs illustrate the visual appearance and incidence of fruit skin OCD obtained for the different treatments.

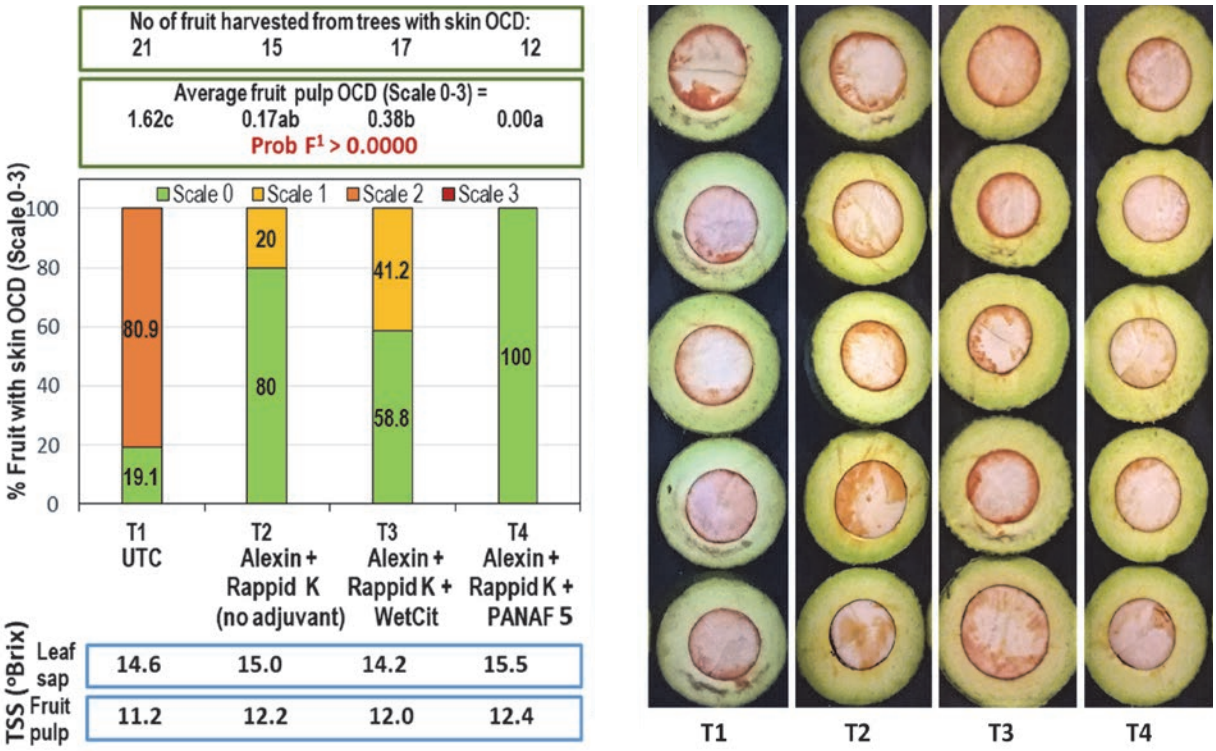

Figure 3: Foliar sprays to improve cold hardiness. The average fruit pulp orchard cold damage (OCD, Scale 0-3) of fruit with fruit skin OCD that remained on the tree, for samples procured from a high nitrogen 'Hass' avocado orchard that is prone to develop OCD. The number of fruit with skin OCD that were harvested per treatment, as well as the leaf sap and fruit pulp TSS values, determined for leaf and fruit samples that were taken 2 days after the -1.5 °C cold event, are indicated. Stats: ANOVA; Fisher LSD (P < 0.05). The photographs illustrate the visual appearance and incidence of fruit pulp OCD obtained for the different treatments.

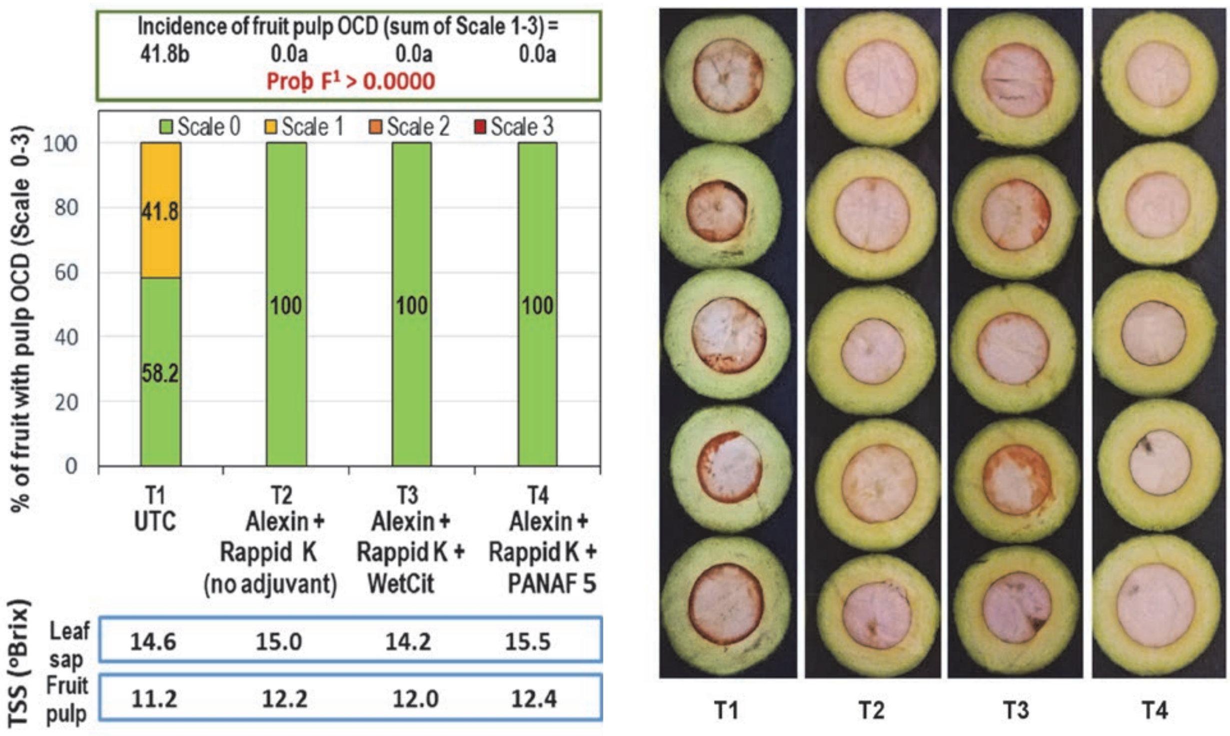

Figure 4: Foliar sprays to improve cold hardiness for 'Hass' avocado. The average fruit pulp orchard cold damage (OCD, Scale 0-3) of count 20 fruit without fruit skin OCD for samples (100 fruit per treatment), procured from a high nitrogen 'Hass' avocado orchard that is prone to develop OCD. The leaf sap and fruit pulp TSS values determined for leaf and fruit samples that were taken 2 days after the -1.5 °C cold event, are indicated. Stats: ANOVA; Fisher LSD (P < 0.05). The photographs illustrate the visual appearance and incidence of fruit pulp OCD obtained for the different treatments.

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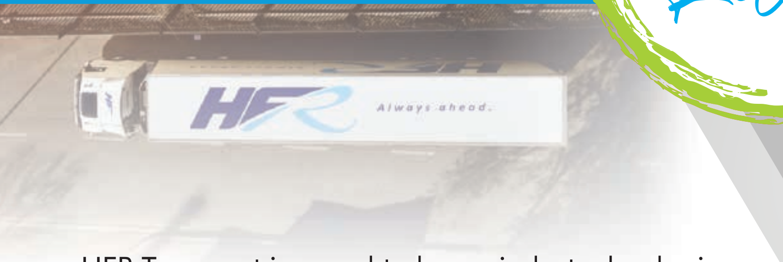

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As count 20 fruit with no visible skin damage is often more prone to show pulp cold damage, 100 fruit (count 20, 20 fruits per tree) were randomly selected from the harvest crates for each treatment. The UTC and the Alexin + Rappid K + WetCit treatments exhibited the lowest leaf sap TSS values (14.6 and 14.2 º Brix, respectively, Fig. 4). This suggests that the inclusion of WetCit as a wetter/penetrator possibly inhibited the absorption of SA, for an unknown reason. Count 20 fruit harvested without visible fruit skin OCD from the UTC treatment trees exhibited a significantly higher incidence of internal pulp OCD (41.8%, Fig. 4) when compared to the three Alexin + Rappid K treatments that showed no pulp OCD. This included only Scale 1 severity values for the specific disorder.

The leaf sap TSS values of Alexin with no wetter [T2] and the Alexin + PANAF 5 [T4] treatments increased to 15 and 15.5 º Brix respectively. The higher TSS of these two Alexin treatments compared to the UTC treatment most likely illustrates the efficacy of SA to increase the TSS content in avocado.

The fruits harvested with and without visible fruit skin OCD from the Alexin + Rappid K + PANAF 5 [T4] treated trees exhibited no internal fruit pulp OCD (Fig. 3 and Fig. 4), indicating the possible use of all three in improving cold hardiness of avocado. Furthermore, PANAF 5 proved to be a good wetter/penetrator to improve penetration of the product into the fruit and leaves of avocado during foliar sprays and also led to improved efficacy of the product.

The fruit and skin nutritional composition give a good indication of how effectively the Rappid K and Alexin were absorbed into the fruit. These two products contain P, K, B and Mg. Analyses of the fruit skin P results indicate that the three Alexin + Rappid K foliar spray applications led to an increase in P with values (Table 2) 0.10%, 0.10% and 0.12% respectively ([T2], [T3] and [T4]), compared to the 0.08% value of the UTC [T1]. [T4] obtained the highest value of 0.12%. This illustrates the effectivity of PANAF 5 as an adjuvant to improve the absorption of P. The skin and pulp K values of the different spray treatments ([T2], [T3] and [T4]) did not differ from the UTC [T1]. This indicates that potassium struggles to penetrate avocado fruit, even with the addition of the two adjuvants. The skin and pulp B content of the Alexin + Rappid K treatment with PANAF 5 added as adjuvant [T4] significantly increased to 91,4 mg/kg and 56,27 mg/kg respectively, when compared to the UTC treatment which obtained values of 57.63 mg/kg and 44.18 mg/kg respectively. The pulp and skin Mg of all treatments ([T1], [T2], [T3] and [T4]) were similar. This indicates that Mg also does not easily penetrate avocado skin. Only the Alexin + Rappid K foliar spray included Cu ([T2], [T3] and [T4]) and the skin Cu values were significantly higher (values of 77.64 mg/kg, 86.5 mg/kg and 108.37 mg/kg respectively), compared to the UTC [T1] that obtained a value of 65.63 mg/kg. PANAF 5 [T4] proved to be more effective than WetCit [T3] when used as an adjuvant to increase penetration of Cu into the fruit skin.

THE WAY FORWARD

- The efficacy of Alexin to increase the TSS of fruits was shown and the positive results surely warrant further research.
- The -1.5 ºC cold event unfortunately occurred quite late in the harvest season. Furthermore, fruit maturity progressed rapidly this season.
- Fruit with a maturity of 36% DM were more tolerant against OCD development and the severity of disorder would have been quite severe if the fruit maturity was 30% DM.
- Hypothetically, fruit sets that are less mature are more prone to developing orchard cold damage.
- Rappid K (potassium pyro-phosphate) in a potato trial of AECI Plant Health led to more even sized tubers and it would be interesting to see how maturity differences in avocados would react to early season applications.
- PANAF 5 proved to be an excellent adjuvant and its penetrating capability improved absorption and movement of nutrients including P, B and Cu into avocado leaves and fruit. However, PANAF 5 could not assist in the better absorption of K into the leaves and fruit skin. During the following season

Table 2: Foliar sprays to improve cold hardiness for 'Hass' avocado. Fruit pulp and skin nutrient content (nitrogen (P), potassium (K), boron (B), magnesium (Mg) and copper (Cu)) were determined of count 20 fruit samples that were procured for each treatment 2 days after the -1.5 ºC cold event, of a 'Hass' orchard prone to develop orchard cold damage

Fruit pulp and skin nutrient content:										
	P (%)		K (%)		B (mg/kg)		Mg (mg/kg)		Cu (mg/kg)	
	Pulp	Skin	Pulp	Skin	Pulp	Skin	Pulp	Skin	Pulp	Skin
T1	0.14	0.08	1.43	1.15	57.63	44.18	0.09	0.10	9.37	65.13
T2	0.10	0.10	1.44	1.08	46.13	36.78	0.08	0.10	7.92	77.64
T3	0.14	0.10	1.52	1.01	74.64	40.98	0.08	0.11	8.42	86.50
T4	0.16	0.12	1.46	0.99	91.40	56.27	0.08	0.11	8.82	108.37

T1 = Untreated control, T2 = Alexin + Rappid K (no Adjuvant), T3 = Alexin + Rappid K (WetCit as adjuvant) and T4 = Alexin + Rappid K (PANAF 5 as adjuvant) it is proposed to include other penetrators:

- In further research, penetrators like Break-Thru® SP 133 (Alchem Group) and Tronic (AECI), with the possible ability to move active ingredients through the wax layer into the plant and how best to use these safely, need to be tested on avocado.
- These penetrators are able to dissolve the plant's protective waxy layers, allowing fertilizers and herbicides to move more effectively into the plant cells.

- To obtain sufficient freeze tolerance to withstand -6 ºC, it may be wise to start treatment earlier during the 2nd year of the project, 12 weeks before expected cold is suggested.
- In collaboration with Linda Greyling (AECI Plant Health) the details of treatments in the 2nd year of the study will be discussed and planned.

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