DEVELOPMENT OF A NON-CHEMICAL TREATMENT SYSTEM FOR AVOCADO AGAINST QUEENSLAND FRUIT FLY FOR INTERSTATE TRADE

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SUMMARY

Most avocado cultivars are known to be particularly poor hosts for fruit flies with field control treatments rarely being required if fruit are harvested at the normal commercially acceptable hard stage. However, current interstate trade and market access for avocados from areas with endemic populations of Queensland fruit fly require that chemical postharvest treatments with dimethoate or fenthion must be applied. An alternative to these chemical treatments is highly desirable given industry and consumer concerns about pesticide usage and the possibility that such treatments may not be available in the future.

Studies in Western Australia demonstrated non-host status for hard Hass avocado for Mediterranean fruit fly allowing interstate trade without the need for chemical postharvest treatment. This project was designed to determine if similar non-host status for Queensland fruit fly could be demonstrated for four cultivars of avocado grown in Queensland and New South Wales i.e. Hass, Lamb Hass, Shepard and Wurtz. An additional aim was to determine if a systems approach incorporating poor host status with a short cold treatment could be used to meet interstate phytosanitary requirements for cultivars which did not meet conditional non-host status requirements.

The field studies undertaken in this project provided quantitative evidence that undamaged skin and flesh of hard avocados on the tree significantly reduced both adult fruit fly oviposition and immature fruit fly development. There were differences between cultivars in suitability for fruit fly infestation with Hass and Lamb Hass at the hard stage meeting the requirements for non-hosts (provided fruit were blemish free). The thinner skinned cultivars, Shepard and Wurtz, although still very poor hosts, were slightly more susceptible to fruit fly attack and did not meet the technical requirements for non-host status.

For Shepard and Wurtz avocados, cold disinfestation trials demonstrated that a combination of host resistance to fruit fly development and a short cold treatment at

2.5±0.5°C for 5 days (compared to export cold treatments of 1°C for 16 days) could provide sufficient phytosanitary security to meet the requirements for interstate trade. Fruit quality studies carried out in conjunction with the disinfestation trials showed no adverse effects on fruit quality due to the treatment. The results of this research will be used to prepare a submission for interstate treatment protocols to be approved for conditional non-host status for Hass and Lamb Hass cultivars and a cold treatment of 2.5±0.5°C for 5 days for Shepard and Wurtz cultivars.

Key words: avocado, host status, Bactrocera tryoni, cold disinfestation

INTRODUCTION

Avocados (*Persea americana* Mill.) have been recorded as hosts for fruit flies in Australia (Hancock *et al.* 2000) however, at commercial harvest stage (hard) they are known to be poor hosts. Studies by De Lima (1995) in Western Australia demonstrated non-host status for hard Hass avocado for Mediterranean fruit fly [*Ceratitis capitata* (Wiedemann)]. These studies found that when hard fruit were exposed to gravid Mediterranean fruit fly for up to three days after harvest, the eggs were unable to complete development. Overseas studies have also shown that some avocado cultivars are non-hosts or very poor hosts for fruit fly. After three years of field studies in Hawaii, Armstrong (1992) concluded that Sharwil avocado was not a host for Mediterranean fruit fly, melon fly [*Bactrocera cucurbitae* (Coquillett)] or oriental fruit fly [*Bactrocera dorsalis* (Hendel)]. Subsequent research showed Sharwil avocado to be a suitable, albeit poor, host of oriental fruit fly with 0.076% of hard mature fruit infested (Liquido *et al.* 1995). This study was carried out in 1992 which was a period of prolonged drought in Hawaii and visual inspection of each fruit in the study suggested that trees in the orchards used were suffering from physiological disorders caused by water stress, nutrient deficiencies and possibly mechanical injuries which predisposed fruit to fruit fly infestation. Laboratory tests on Hass avocado by DPI&F using Queensland fruit fly [*Bactrocera tryoni* (Froggatt)] and papaya fruit fly (*Bactrocera papayae* Drew and Hancock) also indicated very poor infestability (Leach unpublished data).

The currently accepted fruit fly disinfestation treatment for Hass avocados for export to New Zealand is 1°C for 16 days as developed by Jessup (1994) and modified by Hofman *et al*. (2003) to include a preconditioning treatment to improve fruit quality. This treatment exceeds the phytosanitary requirement of 99.9968% mortality (95% confidence) with no survivors from >200,000 insects treated. For interstate trade, a treatment efficacy of 99.5% at 95% confidence (no survivors in 600 insects treated) is acceptable across commodities. However, there is currently no commercially acceptable cold treatment approved for avocados for interstate trade and market access for fruit from areas with endemic Queensland fruit fly populations is dependent on chemical postharvest treatments with dimethoate or fenthion. An alternative to these chemical treatments is highly desirable given industry and consumer concerns about pesticide usage and the possibility that such treatments may not be available in the future. A 16 day cold treatment is generally not an appropriate option for interstate trade when growers want to minimise the time between harvest and sale. However, a shorter treatment time at slightly higher temperature, which still meets the treatment mortality requirements for interstate trade, would provide many practical advantages. In a

separate DPI&F project, a cold treatment of 5 days at 10°C was found to produce a high mortality of Queensland fruit fly in organic tomatoes (Corcoran *et al.* 2001), however such a treatment has not previously been tested on avocados. This aim of this study (Project AVO2003: Development of a non-chemical treatment system for avocado against Queensland fruit fly for interstate trade. Jointly funded by Horticulture Australia and Avocados Australia) was to develop a systems approach to provide phytosanitary security for interstate trade of avocados either by demonstrating conditional non-host status, as shown by Western Australia for Mediterranean fruit fly, or a combination of inherent host resistance and a short cold treatment, which would achieve the required treatment mortality of 99.5% at the 95% confidence level.

MATERIALS AND METHODS

HOST STATUS AND RESISTANCE STUDIES

Trials were conducted in commercial avocado orchards in south east Queensland and northern New South Wales using blocks of trees of four cultivars (Hass, Lamb Hass, Wurtz and Shepard). Experimental procedures were developed firstly, to determine the level of acceptability of hard avocados as a site for fruit fly oviposition while still on the tree and secondly, to determine the level of inherent host resistance to the development of fruit fly eggs and larvae.

The host resistance trials involved exposing caged unblemished hard fruit on trees to known numbers of fertile gravid Queensland fruit flies. The numbers of eggs laid in fruit and the numbers of pupae and flies emerging from fruit were determined. In all trials some of the field fruit were pricked with an entomological pin prior to exposure to fertile gravid Queensland fruit flies. This provided oviposition sites and maximised the numbers of eggs laid. This was intended to demonstrate the inherent physiological resistance of hard avocados to the development of immature fruit flies by comparing the numbers of eggs laid to the numbers of flies surviving to the pupal stage.

In all trials, except for the first Shepard trial, unblemished, unpricked fruit were also exposed to fertile gravid Queensland fruit flies. This was intended to demonstrate the unsuitability of undamaged hard avocados as sites for fruit fly oviposition by comparing the numbers of eggs laid in pricked and unpricked fruit.

In the course of the Shepard trials both the lesser Queensland fruit fly [*Bactrocera neohumeralis* (Hardy)], and the Island fruit fly [*Dirioxa pornia* (Walker)], a secondary pest species normally found in association with overripe, damaged, or fruit fly infested fruit (Hancock *et al.* 2000), were reared from extra fruit harvested for preliminary cold trial tests. The presence of these flies indicated a possible low level of field infestation may have been present. Hence, in future trials thirty unblemished and thirty blemished fruit, three from each of the test trees, were sampled to determine natural infestation.

DEVELOPMENT OF A COLD TREATMENT

Previous research to develop cold treatments for avocados (1°C for 16 days) has been based on treating third instar larvae, the most cold tolerant stage (Jessup 1994), in ripe fruit. This technique provided efficacy data on the cold treatment alone and involved treating fruit at a stage of maturity (ripe) which is not in line with current commercial practice where mature fruit is harvested hard. Because avocados are such a poor host

for fruit fly, treating third instar larvae in fruit at commercial harvest maturity (no softening, dry matter >21%) is only possible if fruit are artificially infested with larvae. This involves using a cork borer to remove a plug of flesh from the fruit, inserting laboratory reared third instar larvae, replacing the plug and sealing it in place. The combination of the damage caused to the fruit and the change in feeding substrate for the larvae may bias the results obtained using this technique. This methodology was therefore considered by the DPI&F research team to be inappropriate in these trials. Instead, methodology was developed to demonstrate that the required level of phytosanitary security for interstate trade could be achieved by using a combination of a cold treatment and the natural resistance of the hard fruit to larval development. Accepted avocado industry standards to define hard mature fruit (i.e. green life and dry matter) were employed to ensure that all treatment development was carried out in compliance with commercial harvest practice.

In normal commercial practice potentially marketable fruit must meet the minimum industry standards for blemish and firmness. If a fruit had been infested within 48 hours prior to harvest, the fruit would at most have minor blemishes only with eggs or first instar larvae present. Any further larval development would lead to obvious blemishes and soft spots on the fruit with subsequent discarding of such fruit prior to any postharvest treatment. Of the two stages of fruit fly development likely to be present in commercially treated fruit, Jessup (1994) showed that mature eggs are slightly more cold tolerant than first instar larvae. Therefore these experiments were carried out using mature eggs as the treatment stage.

The results of the host status tests showed that Hass and Lamb Hass could be considered conditional non-hosts therefore the cold disinfestation treatments were developed for Wurtz and Shepard only.

Fruit source

For these trials, fruit were sourced from commercial blocks. Wurtz had no insecticide treatment in the field and Shepard had not received any insecticide applications for 6-8 weeks prior to harvest. Fruit were blemish free and hard as per normal commercial harvest practice. Ripe fruit were from the same source as the hard fruit however the ripe fruit was either sourced sufficiently in advance to allow the fruit to ripen to the eating soft stage or half the fruit were ripened in temperature and humidity controlled rooms (26°C, 70% RH) in the laboratory while the other half were held in cold rooms (6-7°C) to delay ripening and maintain the fruit at the hard stage for testing.

Experimental design

The primary aim was to develop a cold treatment for mature eggs of Queensland fruit fly in commercial harvest stage fruit (i.e. hard) of both Wurtz and Shepard avocado cultivars. However, after the first Wurtz trial, it was decided to treat mature eggs in ripe fruit as well to provide comparative data on the effects of fruit ripening on treatment efficacy. For three trials with Wurtz and for two trials with Shepard, the treatment parameters were 2.5°C at four holding times, viz 4, 5, 6, and 7 days. For the third Shepard trial, the treatment temperature was 3.0°C instead of 2.5°C for the same holding times.

Infestation method

Prior to infesting, both ripe and hard fruit were individually weighed and sorted into similar weight classes. Fruit selected for the trials were as uniform as possible in size (Wurtz 230-257g, Shepard 190-299g). Hard and ripe fruit were infested at the same time but in separate cages using flies from the same cohort. All trials had 180 treated and 30 control fruit except the first hard Wurtz trial which had 224 treated and 10 control fruit.

Fruit were pinholed 10 times on one side of the fruit using a number 5 entomological pin to provide oviposition sites for the flies, and to assist in obtaining an increased and even distribution of insects within each fruit and more uniform infestation level across all fruit. The fruit were cage infested by placing the fruit with pinholes uppermost into the allocated infestation cages for at least 30 minutes. After 30 minutes the fruit were removed from the cages. Prior to fruit set up and treatment the fruit were held for approximately 24 hours at 26°C and 70% RH to allow the fruit fly eggs to mature.

Control fruit

In the first hard Wurtz trial control fruit were randomly selected from the infested fruit. For all other trials, one fruit from each row within each infestation cage was sampled across the diagonal. Of these fruit, one from each cage was subsampled for the oviposition test. The remainder were kept as control fruit to allow insects to develop to estimate the number of insects treated. Approximately 24 hours after fruit were infested the control fruit were set up individually on gauzed plastic containers to allow excess liquid from fruit breakdown to drain away. The containers were held in large crispers (20L) with gauzed lids to allow ventilation and sawdust in the bottom of the crisper as a pupation medium. After 12-15 days the fruit were examined for any surviving insects and the sawdust sieved to recover pupae. If any larvae were still present in the fruit the fruit were returned to the crispers with the fruit re-examined and the sawdust sieved 3-4 days later. Pupae were collected, counted and placed in takeaway food containers with moistened sawdust to determine adult emergence.

Oviposition test

Subsamples of the infested fruit from each infesting cage were taken to determine the mean number of eggs laid per fruit. Approximately 24 hours after the fruit were infested these fruit were placed in a freezer to stop the development of the eggs in the fruit. At a later date fruit were thawed and examined and the number of eggs per fruit recorded.

Treatment

The treatment was determined as beginning when the core temperatures of all probed fruit dropped to the required treatment temperature ± 0.5°C. The fruit were then held at the required treatment temperature ± 0.5°C, and samples were removed from the cold room at 4, 5, 6 and 7 days after the treatment started. Samples were placed in controlled temperature and humidity rooms at 26°C and 70% RH to rear through any surviving insects as previously described.

Quality Assessments

Fruit quality assessment was done on two replicates of Wurtz and one replicate of Shepard.

The external fruit quality disorders, skin blackening (chilling injury) and skin spotting

were assessed at each withdrawal period prior to ripening as the percentage of the surface area affected using the seven point scale (0 = 0%,

0.5 = 5%, 1 = 10%, 1.5 = 15%, 2 = 25%, 2.5 = 33%, 3 = 50%) (White *et al.* 2001). Each fruit was determined as having a commercially acceptable external quality if there was less than 5% skin damage (Hofman *et al.* 2003).

Fruit firmness during ripening was assessed using gentle hand pressure and was recorded at eating ripe stage using a Chatillon force gauge as the force (in Newtons) required for a 12mm spherical probe modified to penetrate 2mm into the fruit. Fruit weight at assessment was recorded before invasive internal assessment.

At eating ripe stage, skin colour was measured at three sites on the skin surface, using a Minolta Colorimeter model CR300 fitted with an 8 mm orifice and a 0° observer. Data was collected as L'a'b' units and converted to chroma and hue (McGuire 1992). External quality was also assessed at eating ripe with skin blackening and skin spotting recorded as above. Fruit were then cut longitudinally, peeled, and rated for severity of body rots as the percentage of the flesh with lesions (Hofman *et al.* 2003). Severity of stem rot and the internal disorder, vascular browning, was recorded as the percentage of the cut surface area affected. Each fruit was determined as having a commercially acceptable internal quality if the total stem/body rots and/or vascular browning was less than 5%.

Figure 1. Summary of host resistance data for the avocado cultivar Hass.
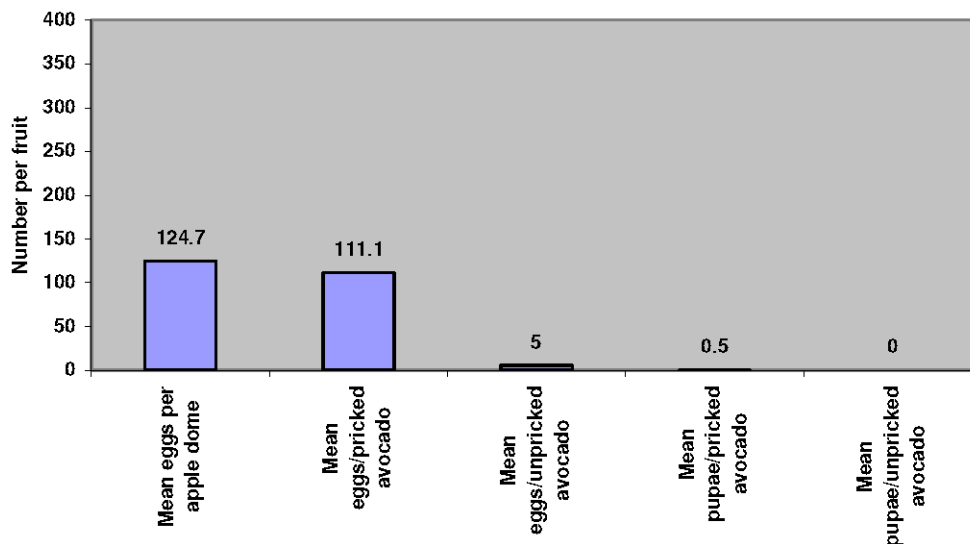

RESULTS AND DISCUSSION

HOST RESISTANCE

By comparing the numbers of eggs in pricked versus unpricked avocados obtained under the conditions of these tests, the effects of undamaged host skin on oviposition could be determined. Furthermore in pricked fruit, by comparing the number of eggs per fruit with the number of pupae per fruit, the effect of mature hard fruit tissue on survival of immature fruit fly stages could also be determined. With the cultivar Hass (Figure 1), undamaged skin reduced oviposition by 96.0%. In pricked fruit, survival of immature

stages to pupation was reduced by 99.5%. This combination of low suitability as a site for oviposition and subsequent low survival of immatures is reflected in the results of the assessment of immature survival in unpricked fruit in which there were no survivors making Hass a suitable candidate for conditional non-host status.

These same comparisons for the cultivar Lamb Hass (Figure 2) showed undamaged skin reduced oviposition by 97.1%. In pricked fruit, survival of immatures to pupation was reduced by 99.1%. The level of oviposition reduction and immature development suppression were even more pronounced than in Hass. Again, with no survival of immatures in unpricked fruit, this cultivar would be a suitable candidate for conditional non-host status.
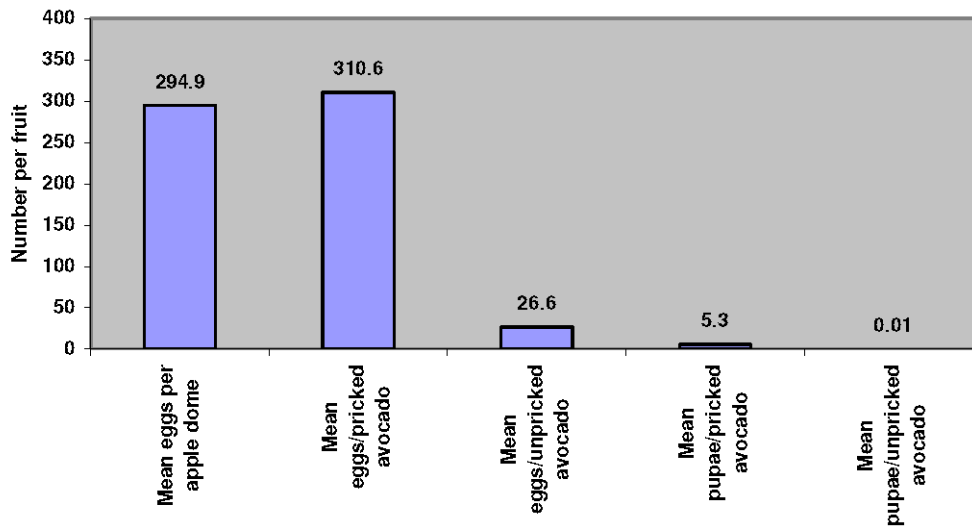
**Figure 2. Summary of host resistance data for the avocado cultivar Lamb Hass.**
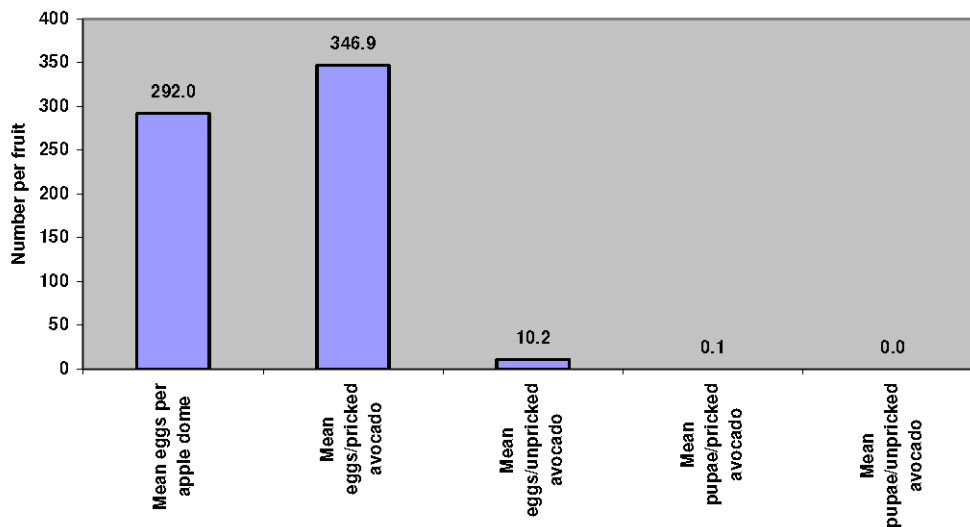
The same comparisons for the cultivar Wurtz (Figure 3), showed oviposition was reduced by 91.4% in unpricked fruit. In pricked fruit, survival of immatures to pupation was reduced by 98.3%. These factors were not sufficient to completely suppress immature development as shown by the low level of survival (0.01 pupae per fruit) in unpricked fruit. Although very low, such a level of survival makes Wurtz unsuitable as a candidate for conditional non-host status.

Comparisons for the cultivar Shepard (Figure 4) showed oviposition in pricked fruit to be higher than the other cultivars (423.7) however data was not collected to enable a comparison between the numbers of eggs in pricked vs unpricked fruit. Survival of immatures to pupation was reduced by 98.0%, less than the corresponding reductions with the other cultivars and indicating that Shepard fruit were the most suitable for immature development. Although no adult Queensland fruit fly emerged, the combination of the higher survival to pupation and the survival to adult of *D. pornia* makes Shepard unsuitable as a candidate for conditional non-host status.

Figure 3. Summary of host resistance data for the avocado cultivar Wurtz.

Figure 4. Summary of host resistance data for the avocado cultivar Shepard.
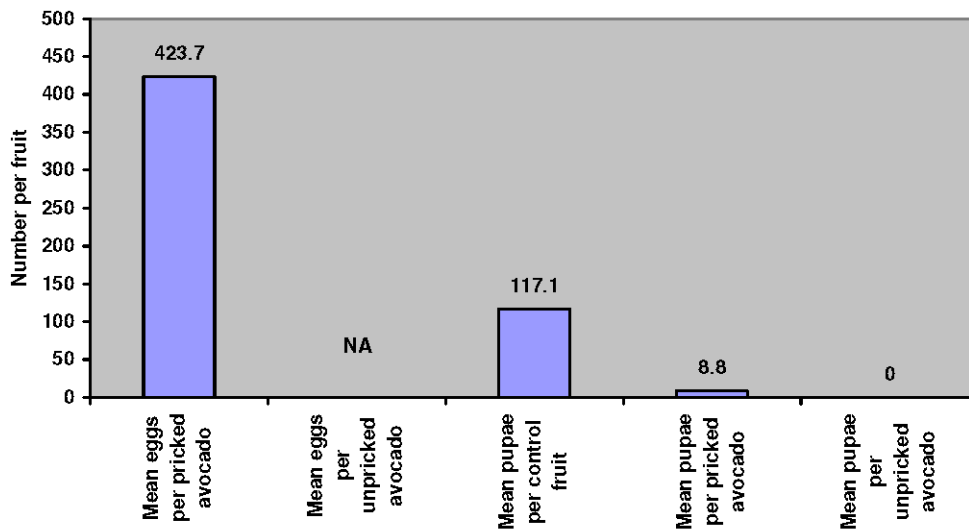
DEVELOPMENT OF A COLD TREATMENT

Treatment

A summary of the treatment times and temperatures required to achieve the required level of phytosanitary security (99.5% at 95% confidence) in both ripe and hard Wurtz and Shepard avocados is given in Table 1.

Fruit Quality

Fruit quality responses of Wurtz and Shepard avocado following natural ripening at 20°C and 85 % RH or cold disinfestation at 2.5°C ± 0.5°C for 4, 5, 6 and 7 days are shown in Table 2 and Table 3 respectively.

Wurtz

Weight loss of Wurtz avocado was minimal after cold disinfestation at 2.5°C for 4, 5, 6 and 7 days in both replicates and was at similar levels to control fruit. Fruit firmness at assessment in replicate 1 ranged from 6.4 -7.0N with the exception of the 6 days treatment which was 10.6N where some fruit remained hard at assessment. Firmness of control fruit in replicate 2 was 6.2N compared to 6.2 -6.8N for cold treated fruit.

Skin colour intensity (Chroma) of fruit from day 6 and 7 treatments was lowest in replicate 1. In replicate 2, skin chroma values of fruit from all treatments were slightly higher than those of control fruit. Skin colour saturation (Hue) was similar in value for control and treated fruit for both replicates.

Table 1. Summary of treatments achieving required level of phytosanitary security.

Cultivar	Fruit maturity	Treatment temperature (°C)	Treatment time (days) required to exceed 99.5% efficacy
Wurtz	Ripe	2.5±0.5	4
	Hard	2.5±0.5	4
Shepard	Ripe	2.5±0.5	5
	Hard	2.5±0.5	5
Shepard	Ripe	3.0±0.5	4
	Hard	3.0±0.5	5

Skin spotting, which became evident during ripening, was slight in severity in fruit after cold disinfestation at 2.5°C for 4, 5, 6 and 7 days and was recorded at similar levels in control fruit in both replicates. No external chilling injuries were observed in ripened cold treated fruit from any withdrawal period. Mild vascular browning of low severity was recorded only in the stem end of ripe fruits and was present in treated and control fruit. Body and stem rot severity in ripe fruit were generally low in all treatments including control fruit.

Shepard

Weight loss at assessment of control fruit (6.5%) was similar to 6 and 7 day treatments (6.5%, 6.4%) and lower for 4 and 5 day treatments (5.8% and 5.9%) respectively. Fruit firmness of control fruit (7.4N) was moderately higher than fruit from all treatments (3.5 - 4.7N).

Skin colour intensity (Chroma) was similar between untreated (16.4) and day 7 cold treated (16.5) fruit, but was higher following the 4, 5 and 6 day treatments (Table 3). Skin colour saturation (Hue) was similar in value for both treated and control fruit. Skin spotting and body rot severity in ripe fruit in all treatments were slight and were at similar levels to control fruit. External chilling injury was not observed in treated fruit. Vascular browning severity was very low in all treatments and recorded only in the stem end of affected fruits. Stem rots were also of low severity and did not differ between control and treated fruit.

Table 2. Fruit quality characteristics[#] of Wurtz avocado following cold disinfestation at 2.5°C for 4, 5, 6 and 7 days.

Treatment (days at 2.5°C)	Wt Loss (%)	Firmness (N)	Skin Colour Hue	Chroma	Skin Spotting (0-3)	Vascular Browning (0-3)	Body Rots (0-3)	Stem Rots (0-3)
Replicate 1								
0 (control)	3.6 ± 0.13	7.0 ± 0.18	-55.1 ± 0.24	19.2 ± 0.53	0.3 ± 0.07	0.04 ± 0.03	0.1 ± 0.06	0.1 ± 0.06
4	3.5 ± 0.15	6.7 ± 0.21	-54.4 ± 0.31	18.8 ± 0.83	0.2 ± 0.07	0.02 ± 0.02	0.1 ± 0.06	0.1 ± 0.07
5	3.7 ± 0.11	7.0 ± 0.22	-55.2 ± 0.35	18.6 ± 0.89	0.2 ± 0.07	0.04 ± 0.03	0.1 ± 0.05	0.1 ± 0.06
6	3.7 ± 0.1	10.6 ± 0.68	-54.3 ± 0.63	16.4 ± 0.41	0.3 ± 0.08	0.04 ± 0.03	0.2 ± 0.06	0.2 ± 0.07
7	3.7 ± 0.11	6.4 ± 0.18	-55.1 ± 0.33	16.7 ± 0.35	0.3 ± 0.08	0.04 ± 0.03	0.2 ± 0.07	0.0 ± 0.03
Replicate 2								
0 (control)	3.2 ± 0.1	6.2 ± 0.44	-54.8 ± 0.35	17.1 ± 0.48	0.2 ± 0.07	0.1 ± 0.05	0.1 ± 0.05	0.2 ± 0.09
4	3.4 ± 0.15	6.2 ± 0.93	-55.7 ± 0.41	18.7 ± 0.79	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.06
5	3.4 ± 0.11	6.4 ± 0.2	-55.3 ± 0.27	18.3 ± 0.61	0.1 ± 0.06	0.1 ± 0.06	0.1 ± 0.03	0.04 ± 0.03
6	3.3 ± 0.1	6.1 ± 0.17	-58.2 ± 0.28	18.3 ± 0.59	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.06
7	3.4 ± 0.07	6.8 ± 0.28	-55.8 ± 0.32	17.7 ± 0.52	0.2 ± 0.07	0.04 ± 0.03	0.1 ± 0.05	0.1 ± 0.08

[#] Skin spotting, vascular browning, body rots and stem rots were rated as the percentage of the surface area affected using the seven point scale (0 = 0%, 0.5 = 5%, 1 = 10%, 1.5 = 15%, 2 = 25%, 2.5 = 33%, 3 = 50%). Data expressed as means including standard error of mean.

Table 3. Fruit quality characteristics[#] of Shepard avocado following cold disinfestation at 2.5°C for 4, 5, 6 and 7 days.

Treatment (days at 2.5°C)	Wt Loss (%)	Firmness (N)	Skin Colour Hue	Chroma	Skin Spotting (0-3)	Vascular Browning (0-3)	Body Rots (0-3)	Stem Rots (0-3)
0 (control)	6.5 ± 0.18	7.4 ± 0.57	-55.7 ± 0.28	16.4 ± 0.33	0.2 ± 0.06	0.02 ± 0.02	0.1 ± 0.04	0.1 ± 0.04
4	5.8 ± 0.27	4.7 ± 0.25	-56.1 ± 0.19	17.0 ± 0.41	0.1 ± 0.04	0.03 ± 0.02	0.1 ± 0.03	0.1 ± 0.02
5	5.9 ± 0.26	3.5 ± 0.14	-56.4 ± 0.36	17.2 ± 0.53	0.1 ± 0.04	0.01 ± 0.01	0.1 ± 0.04	0.1 ± 0.02
6	6.5 ± 0.17	3.9 ± 0.11	-56.8 ± 0.21	18.5 ± 0.46	0.2 ± 0.04	0.03 ± 0.02	0.1 ± 0.03	0.1 ± 0.03
7	6.4 ± 0.14	3.8 ± 0.12	-55.8 ± 0.18	16.5 ± 0.43	0.2 ± 0.05	0.03 ± 0.02	0.04 ± 0.02	0.1 ± 0.02

[#] Skin spotting, vascular browning, body rots and stem rots were rated as the percentage of the surface area affected using the seven point scale (0 = 0%, 0.5 = 5%, 1 = 10%, 1.5 = 15%, 2 = 25%, 2.5 = 33%, 3 = 50%). Data expressed as means including standard error of mean.

Commercial acceptability was determined as the point where each fruit had an external

quality of less than 5% skin damage and an internal quality of less than 5% stem and body rots or vascular browning combined (Table 4).

Table 4. The percentage of ripe fruit of Wurtz and Shepard avocado with acceptable external and internal quality either without treatment or following disinfestation at 2.5°C ± 0.5°C for 4, 5, 6 and 7 days.

Treatment (days at 2.5°C)	External quality[a] (% acceptable fruit)		Internal quality[b] (% acceptable fruit)	
	Wurtz	Shepard	Wurtz	Shepard
0 (control)	67	70	79	87
4	74	77	84	82
5	76	77	73	85
6	73	80	81	87
7	67	72	75	87

[a] Based on less than 5% of skin with disorders.
[b] Based of less than 5% of the flesh with rots or internal disorders combined.

The results of this study have shown that a cold disinfestation treatment at 2.5°C for 4, 5, 6 and 7 days without any pretreatments or preconditioning treatments did not result in the development of external chilling injuries on either Wurtz or Shepard avocado cultivars. Mild skin spotting, seen as 1-2 mm black lesions, developed during ripening on both untreated and treated fruit and was not increased as a result of the cold treatment. Skin spotting is an external disorder often a result of compression damage during harvesting or packing and in Hass cultivars is commonly seen in early ripening while the skin is still green.

CONCLUSIONS

The overall aim of this project was to develop a non-chemical treatment system for avocado against Queensland fruit fly for interstate market access. This was a high priority for the avocado industry in areas with endemic Queensland fruit fly populations because of the likelihood that current postharvest chemical disinfestation treatments may be unavailable for some commodities in the near future. Although avocados have long been recognised as poor hosts for fruit flies in general, no research had been undertaken with Queensland fruit fly to quantify host resistance to either oviposition or to immature fly development and no data was available to quantify the differences in susceptibility of different avocado cultivars. Furthermore, an appropriate and commercially acceptable cold disinfestation treatment for Queensland fruit fly for interstate trade has not previously been developed as an alternative to the current chemical treatments.

This project has successfully addressed all of the above research requirements. Field studies with on-tree fruit of four cultivars have quantified the natural resistance of hard mature undamaged avocados to fruit fly infestation. With the use of a range of carefully planned "controls", the additional unsuitability of hard avocado fruit tissue for immature fruit fly development has also been verified. Differences in host resistance between four

cultivars have been quantitatively demonstrated for the first time. Two cultivars, Hass and Lamb Hass, have been shown to be conditional non-hosts for Queensland fruit fly provided fruit is hard with undamaged skin. Results of the field host resistance studies have justified the development of a cold disinfestation treatment against mature eggs of Queensland fruit fly for the two cultivars, Shepard and Wurtz, which did not meet conditional non-host requirements. The short cold treatment (5 days at 2.5°C) meets the efficacy requirements for interstate trade (99.5% efficacy at 95% confidence) and is a much more acceptable option for growers than the long cold treatment (1°C for 16 days) which was developed to meet export requirements.

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