AVOCADO FRUIT ROTS: A REVIEW OF INDUSTRY FUNDED RESEARCH

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ABSTRACT

Over the last 25 years there has been considerable research on avocado fruit rots. Rot potential can theoretically be reduced from 100% to 6.8% by using copper fungicide application, postharvest Sportak® (prochloraz) application, transport at 6^{o} C, and ripening before sale at 15^{o} C. Orchard surveys have shown that growers generally do not use an adequate copper spray programme and that if calcium application was increased, fruit quality could be enhanced. Other changes in practice have improved fruit quality, such as in-line spray application of insecticides for fruit destined for the USA market. Dipping fruit in an insecticide bath without the inclusion of a fungicide provided a 'spore bath' that inoculated the fruit with rot fungi. Fruit imbibed with water are more susceptible to handling damage that may provide entry points for avocado rot fungi. Consequently there is a recommendation that avocado fruit are no longer harvested in the rain. A number of alternatives to copper sprays and postharvest Sportak® application have been tested, as well as different postharvest storage conditions. From these preliminary results, a number of strategies have been identified as promising for providing further improvement to postharvest quality of avocado fruit.

INTRODUCTION

Avocados need to be considered as a delicate commodity with a reasonably short storage life (currently about 34 days; Dixon, 2001). When avocado quality deteriorates, it is almost always due to fungal fruit rots (Dixon, 2001). Fungal fruit rots are the single most important determinant of fruit quality in New Zealand avocados.

Fungal diseases are a result of an interaction between environment, inoculum load and tree health. Disease expression can be minimized by manipulating the environment, tree health or by direct reduction of inoculum (fungal spores, fragments of infected leaves or twigs and rotten or mummified fruit).

Throughout the avocado production chain fruit quality is influenced by: orchard factors (e.g. irrigation, nutrition, fungicide spray programmes), damage during picking, maintenance of the cool chain during storage and transport, water loss, and time fruit is held before sale (Milne, 1998). At each point in the production chain a range of actions can be taken to reduce rots (Table 1).

The complexity of the disease problem in avocados suggests that there is not likely to be a single solution to controlling the incidence of rots. There is unlikely to be one simple process and/or chemical that will cure our disease problem. Instead the solution will be found in incremental changes throughout the avocado production chain. It is therefore important that all parts of the production chain are optimized.

This review will focus on outcomes from industry funded research carried out in New Zealand, with some reference to key research outcomes from overseas. The overall goal is to increase our understanding of fungal fruit rots with the aim of improving disease control strategies.

The fungal pathogens

Postharvest diseases of avocado fruit in New Zealand are caused by five main fungi; Anthracnose (*Colletotrichum gloeosporioides*), *Colletotrichum acutatum*, *Botryosphaeria parva*, *Botryosphaeria dothidea* and *Phomopsis* spp. (Hartill, 1991a; Everett and Hallett, 1997). Body rots (infection through the body of the fruit) or the stem-end rots (infection through the stem of the fruit) can result from infection by each fungus, although *Phomopsis* is seldom isolated from body rots. In Australia and Israel, the most important fungus is *C. gloeosporioides,* which infects latently throughout the avocado growing season (Coates *et al.*, 1993; Prusky *et al.*, 1991). In contrast the most common fungus in New Zealand is *B. parva*, as both a stem-end invader and through the side of the fruit (Everett and Pak, 2001).

The most common fruit rot fungi in avocados vary from region to region (Hartill, 1991b; Everett, 1999a, 2000b, 2001b), with the two *Colletotrichum* species being more important in the northern avocado growing districts. In addition, each growing season differs in terms of the predominant fungi causing stem-end rots and body rots (Everett 1999a, Everett 2000b, Everett 2001b). The temperature optima of *Colletotrichum* and *Botryosphaeria* (Everett and Chynoweth, 2002b) is different, with *Botryosphaeria* favouring cooler growing conditions, suggesting that the difference in importance of the fungi is related to cooler growing conditions in the Bay of Plenty compared to those in Northland (Figure 1). Such information will allow control strategies to be targeted to the individual requirements of the different growing districts.

Infection timing

Body rots

In-depth understanding of where these pathogens reside in the orchard, and where and under what conditions they infect fruit, is essential in planning effective control strategies. Studies carried out in New Zealand suggest that infection by body rot fungi commonly occurs immediately before or after harvest, in summer (Hartill, 1988a; Everett, unpublished data). Most control of rots took place from fungicide applications in the four months from September to February (Everett, 2000b). Laboratory studies on the temperatures required for germination of spores showed that for three fungi temperatures during winter in New Zealand inhibit germination (Figure 1). However, *Botryosphaeria parva* can germinate readily at 10^{o} C (Everett and Chynoweth, 2002b).

Table 1. The avocado production chain, practices that benefit fruit quality.

Step in Production Chain	Reduce inoculum	Manipulate environment	Improve tree/fruit health
The orchard	Apply fungicides Dead twig removal	Skirt and mulch Irrigate during flowering	Optimise calcium nutrition Control *Phytophthora*
Picking	Apply fungicides to cut stalks	Don't pick turgid fruit	Pick into small lugs or onto layers of bubblewrap Leave longer stalks
Packing	Remove twigs/leaves Spray fruit in-line	Minimise pick to pack times Minimise water loss	Maintain coolchain Apply wax + fungicide
Transport	Reduce ethylene e.g. gas powered forklifts not petrol	Use CA/MA Adjust storage temperature according to fruit maturity	Use CA/MA Maintain coolchain
Point of Sale	Remove rotten fruit	Ripen at 15^{o} C	Maintain even temperatures Sell as quickly as possible (reduce fruit age)

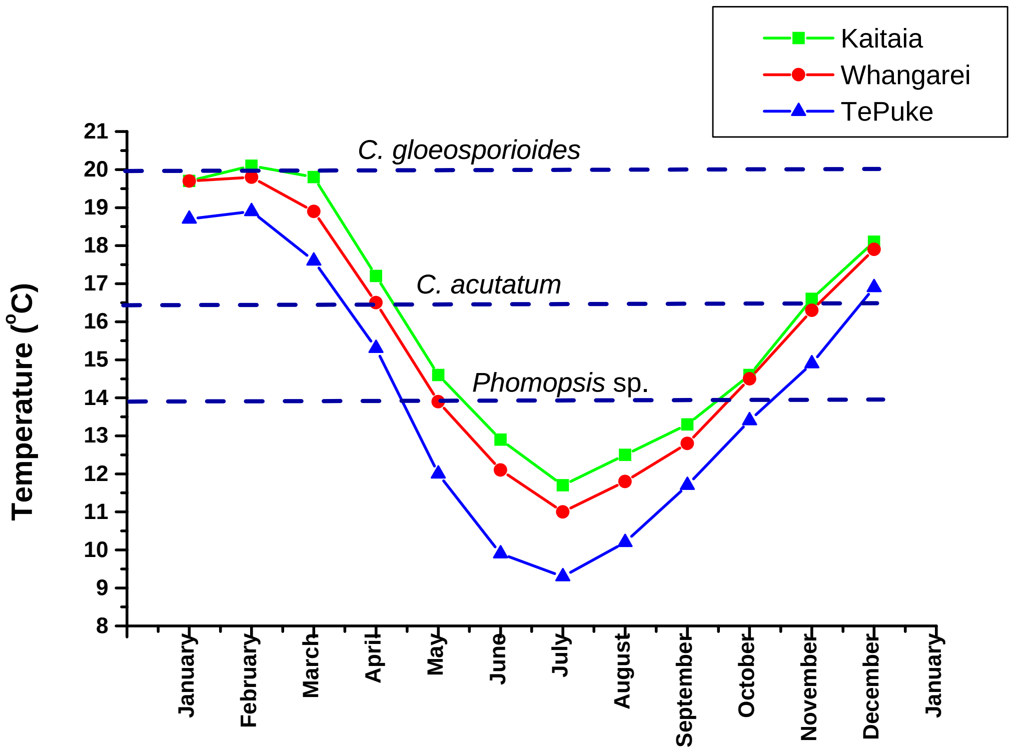

Figure 1. Mean daily temperatures in three districts in New Zealand. Horizontal lines represent the minimum temperatures required for germination by spores of these fungi after 24 hours.

Stem-end rots

Stem-end rots infect through the cut surface of the fruit stalk end at harvest (Hartill and Everett, 2002; Everett and Chynoweth, 2002a).

Infection pathways

Body rots

Colletotrichum gloeosporioides can form latent infections throughout the growing season (Peterson, 1978; Coates *et al.*, 1993; Prusky *et al.*, 1991). Spores germinate to form appressoria which grow and penetrate the fruit during ripening. Appressoria of *C. acutatum* have been observed on avocado in New Zealand, but inoculation studies with *C. acutatum* failed to confirm infection of unwounded fruit (Everett and Hallett, 1997).

Stem-end rots

In avocados there is little evidence for endophytic (through the water conducting tissue) infection. Only *Phomopsis* has been isolated frequently from the internal stem tissue (Hartill, 1993) but may be infecting at flowering to cause stem-end rots in fruit (Everett and Stevens, 1998). Stem-end rots start at the cut stalk and grow down the stem into the fruit flesh (Hartill and Everett, 2002; Everett and Chynoweth, 2002a). In clipped fruit another infection pathway may be by initial uptake of some spores by the retreating water column into the drying stalk (Hartill *et al.*, 2002).

Stem ends of plucked fruit are almost always infected more than clipped fruit (Hartill and Sale, 1991a; Woolf *et al.*, 1997a; Hartill and Everett, 1997; Hartill and Everett, 2002). Plucking fruit may release more spores than the clipping method or the stem remnant in clipped fruit acts as a barrier to infection.

Inoculum sources

There are several potential sources of inoculum in an avocado orchard. These include: dead tissue on twigs and leaves in the canopy, dead fruit in the canopy, and dead fruit, twigs and leaves in the mulch once they fall off the tree. Other potential sources are shelter belts and adjacent orchards. *Colletotrichum* spp. spores are commonly found on dead branches and twigs (Hartill, 1989b), but all pathogens can be isolated from dead branches and twigs (Everett, unpublished data). *Colletotrichum* spp. were predominant in bark from young twigs and other fungi were found equally in both young and old bark. Green leaves are infected mainly by *Colletotrichum* spp. (Everett, unpublished data), and dead leaf tissue by all fungi (Everett, 2002).

Initial studies (Hartill, 1987) showed a relationship between ring-neck scars (decaying tissue on the stem attached to the fruit) and stem-end rots caused by *Botryosphaeria parva*. Subsequent investigation has failed to confirm these findings (Hartill, 1989a).

Shelter belts can also be an important source of inoculum for postharvest pathogens. Avocado pathogens have been isolated from *Cryptomeria japonica*, *Casuarina cunninghamiana* and poplar (Everett, 1994; Pennycook, 1985). Shelter should be included in spray programmes or replanted with species that do not harbour postharvest pathogens. Avocado pathogens do not infect bamboo (Manning, pers. comm.). Eucalypts and bamboo were the species least susceptible to *B. parva* in inoculation tests involving eight common shelter belt trees (W.F.T. Hartill pers. comm.). Other shelter belt species need to be tested for their susceptibility as hosts for avocado pathogens.

Fruit maturity and rots

The incidence of postharvest rots changes as the harvest season progresses. Fruit harvested monthly from September to April, started with high rot incidence that decreased until December, then increased again in January to a constant level (Hartill, 1989c). Other studies over different time periods are consistent with this finding (Everett, 2000b; Pak, 2001).

The orchard

Reducing inoculum with fungicides

During the last 20 years, a large number of fungicide field trials have been carried out for control of postharvest rots of avocados in New Zealand (e.g. Hartill *et al.*, 1990; Sale, 1993; Hartill *et al.*, 1994; Hartill and Sale, 1995b; Everett, 2001a). Fungicides tested include Aliette® (fosetyl-al), Amistar® (azoxystrobin), Bavistin® (carbendazim), Benlate® (benomyl), Captafol® (difolatan), formulations of copper, formulations of phosphorous acid, Shirlan® (fluazinam), Sportak® (prochloraz), and Stroby® (kresoxim-methyl). Copper fungicides have consistently performed the best of those tested, and in combination with Benlate during flowering and early fruit set, followed by postharvest dipping in prochloraz, provides optimal rot control. Postharvest rots were reduced from 72% of fruit with rots to 24%, using this combination of treatments (Hartill *et al.*, 1992). The advantage of the combination fungicide sprays is that the use of Benlate® reduces the total number of copper sprays.

In a survey of orchards 6-9 fungicide applications per year were identified as the optimal number for adequate rot control (Everett, 1999a, 2000).

Other fungicides

Application of Benlate® by itself provides variable control (Hartill *et al.*, 1992; Sale, 1993) while Aliette® and Foli-R-Fos® provide moderate control, but were not as effective as copper in other trials. Only Amistar®, Foli-R-Fos® and Benlate® performed comparably well to copper (Everett, 2001a; Hartill *et al.*, 1992, Hartill *et al.*, 1994; Hartill and Sale, 1995b).

Cultural control

Dead wood and mummified fruit in the canopy are a potential inoculum source (Hartill *et al.*, 1989), but dead wood removal does not consistently reduce rots (Hartill *et al.*, 1990, 1992). In Australia it is recommended that removing the skirt around avocado trees improves aeration, decreases humidity, and thus fungal infections (Cooke and Coates, 1994). Fruit from the lower part of the tree had more rots than fruit from the higher parts (Everett, 2001b). Canopy density has been identified as a factor influencing rots in New Zealand (Everett, 1999a, 2000b). In New Zealand skirting has not been recommended as a practice because of the importance of mulch retention.

Optimising tree health

A survey of fruit from 23 orchards (Everett, 2000b) identified mineral content of the fruit as having an important influence on rots, in particular the ratio of calcium and magnesium to potassium (Ca+Mg/K). Growers have consequently increased the application of calcium to their trees to such an extent that the Ca+Mg/K ratio in fruit no longer limits fruit quality (Everett, 2001b). Fruit from orchards with trees showing symptoms of *Phytophthora* had more rots than fruit from healthy orchards (Everett, 1999a, 2000a). Control of *Phytophthora* infections may enhance tree health and subsequent fruit quality.

Postharvest

Fruit age

Inoculation of fruit at harvest with *C. acutatum* followed by monitoring disease development during coolstorage showed that this pathogen grows down the stem end and into the fruit flesh in the coolstore, and that penetration into the fruit flesh takes 32-37 days (Everett and Chynoweth, 2002a). This is similar to results from the outturn monitoring where there was an exponential increase in stem-end rots after a fruit age of 34 days (Dixon, 2001; Dixon and Pak, 2002).

Reducing inoculum

Prochloraz (*Sportak*®)

Prochloraz (Sportak®) has proved effective for control of postharvest rots of avocados, and on average over numerous studies has reduced rots by a half (e.g. Hartill and Sale, 1990; Hartill, 1991b; Hartill *et al.*, 1992; Sale, 1993; Hartill *et al.*, 1994 b). Application within 24 hours after harvest provides acceptable control (Table 2), although application within 2 hours provides best control.

Table 2. Effect of increasing time after harvesting before Sportak® application on fruit rots.

		hours after picking fruit treated				
	not dipped	0	2	4	12	24
no.isolations	73	28	27	35	34	40

Unsuccessful novel treatments

The novel treatments that have no effect on rots include: elicitors (chemicals that stimulate the plant's natural defences against rots) such as methyl jasmonate, biological control agents (micro-organisms that produce natural substances that can control rots) such as Serenade®, and compounds that are generally regarded as safe (GRAS compounds), 76% ethanol, Neem oil (a plant extract), Avosan® (a poly-amino-glucose), Sporekill® (dideclydimethylammonium chloride), and food grade antioxidants (Xedaphen-20 and butylated hydroxy toluene (BHT) + citric acid) and CO_2 shock treatment (30% CO_2 in air for 24 hours or 3 days) (White *et al.*, 1993; White *et al.*, 1999; Everett, 2000a).

Successful novel treatments

Several novel treatments controlled rots, these were; acidified permanganate, Janola® (hypochlorite) and biological control. Permanganate that was not acidified turned the stem button black.

Fungicide alternatives to prochloraz (Sportak®)

Three fungicides from the same chemical group (the benzimidazoles) were tested. These were TBZ or Tecto® (thiabendazole), Benlate® (benomyl) and Bavistin® (carbendazim) (Hartill *et al.*, 1994). Benlate® performed the best of the above fungicides. However, this chemical has been removed from sale. Of the other benzimidazole fungicides tested, thiabendazole (TBZ or Tecto®) was the next most effective. Carbendazim had very little effect.

Another fungicide in the same group as prochloraz (the imidazoles), Fungaflor® (imazalil) was not effective. Two triazole fungicides, Baycor® (bitertanol) and Bumper® or Tilt® (propiconazole) controlled rots, but were were not as effective as prochloraz

(Hartill *et al.*, 1986). Another triazol fungicide, Nustar® (flusilazol), controlled rots as well as prochloraz (Hartill, 1989d). The fungicides Rappor Plus® and Panoctine Super® (guazatine or iminoctadine) were ineffective. These fungicides are not used commercially. Foli-R-Fos® did not control rots when applied as a dip, but when applied in the orchard or imbibed into fruit there was good control of rots. Applying fungicides to the picking wound immediately after harvest in the orchard (Hartill, 1995; Hartill and Everett, 1997; Hartill and Everett, 2002) can provide good control of stem-end rots, but the best chemical of those tested, Benlate®, is no longer available.

Other control methods

Temperature management
Of the postharvest measures used for disease control, the most useful is temperature management. Hopkirk *et al.*, (1994) showed that coolstoring fruit at 6^{o}C could reduce rots by 59% when ripened at 15^{o} C (Table 3).

Table 3. Rots in coolstored fruit compared to non-coolstored fruit.

storage temperature	ripening temperature	% healthy fruit	% efficacy
20	20	0	-
6	15	59	59
6	20	36	36
6	25	0	-
6	30	0	-

South African investigators alter storage temperatures in relation to fruit maturity, and have stepped temperature regimes during coolstorage (Milne, 1998).

Other storage optimization methods
Many other aspects of the postharvest handling chain have been investigated for their effect on rots and include; reducing or accelerating moisture loss (White *et al.*, 1996; Hopkirk *et al.*, 1990; Johnston and Banks, 1996), removing or adding ethylene (Woolf *et al.*, 1997b; Hopkirk *et al.*, 1990), investigating the effect of peel damage as a result of brushing (Hartill, 1989e), of delay before coolstorage (Hopkirk *et al.*, 1990), controlled atmospheres (Hartill and Yearsley, 1989), waterblasting (Woolf *et al.*, 1999), imbibing fruit with water (Everett *et al.*, 2001), and the effect of dipping in a pyrethrum solution on inoculum load (Everett, 2000a). Isolations from samples of dipping liquid showed the number of *Colletotrichum* spores in the pyrethrum solution increased as more fruit were dipped. The practice of dipping in pyrethrum has been abandoned and there is a move away from handling wet fruit. Subsequent adoption of in-line spray application of insecticides to prevent inoculation by dipping has resulted in almost complete disappearance of the 'measles' rot symptom observed in green fruit exported to USA.

Controlled atmosphere (CA) or modified atmosphere (MA) storage may reduce postharvest rots (Milne, 1998). Both CA and MA storage have resulted in loss of quality in experiments in New Zealand (Hartill and Yearsley, 1989), and one CA system used to ship fruit to the USA had very poor quality fruit (Dixon, 2001). Concentrations of CO_2 at 10% prevented development of anthracnose for 3-4 weeks in the varieties 'Fuchs' and 'Waldin' stored at 7.2^o C (Spalding and Reeder, 1975). Further investigation using different atmosphere mixes may provide conditions that could maintain fruit quality. The effects of water loss on fruit quality are inconclusive at present (Lallu *et al.*, 2002).

Ethylene absorbents in boxes of fruit did not reduce postharvest rots (Hartill and Yearsley, 1989; Hopkirk *et al.*, 1990; White and Forbes, 1994). There was a consistent detrimental effect on rots of installing liners in boxes (Johnston and Banks, 1996; Hopkirk *et al.*, 1991). Application of waxes to the fruit surface increased postharvest rots (Johnston and Banks, 1996), which agrees with results of overseas researchers (Darvas, 1982).

Delays into coolstorage

Fruit placed in the coolstore 12 hours after picking had fewer rots than those placed in the coolstore 6 hours, or 24 hours or longer after picking (Hopkirk *et al.*, 1990). It is unclear if these results were due to time delay, water loss, or some other factor.

Waterblasting

Waterblasting is inconsistent in its effect on postharvest rots. Further testing has shown that it is not a practical method for disease control (Dixon and Pak, 2002).

CONCLUSIONS

Over the last 25 years the NZ avocado industry has funded considerable research effort into avocado fruit rots. From research trials by a number of workers it has been shown that copper fungicide application in the orchard reduces rots by 58%, postharvest prochloraz application a further 55%, transport at 6^o C another 36%, and ripening before sale at 15^o C 59%. If all these practices are followed, initial rot levels can theoretically be reduced from 100% rot potential to 6.8%. An orchard survey carried out in 1999 showed that growers were not applying adequate levels of copper, and that increased application of calcium would lead to enhanced fruit quality. During the three years of the survey, growers improved their copper fungicide programme and their calcium applications, with a concurrent improvement in fruit quality that was unrelated to weather.

Further changes in practice which have led to improved fruit quality, include the installation of in-line spray application of insecticides for fruit destined for the USA market. Dipping fruit in an insecticide without the inclusion of a fungicide was shown to be detrimental to fruit outturn quality. Fruit imbibed with water have been shown to be more susceptible to handling damage, which is thought to provide entry points for avocado rot fungi. Consequently, wherever possible fruit should not be harvested in the rain. Changes to these practices resulted in the problem known as 'measles', large brown spots developing in green fruit in coolstorage, largely disappearing. A number of alternatives to orchard application of copper and postharvest prochloraz application have been tested, as well as different postharvest storage conditions. From these preliminary results, a number of strategies have been identified as promising for providing further improvement to postharvest quality of avocado fruit.

Additional orchard management practices that reduce fungal infections include: skirting, mulching with bark, removal of dead twigs, branches and rotten fruit from the orchard under story, and thinning of the canopy by pruning. Optimizing fruit quality after harvest requires storage at low temperatures, the appropriate use of postharvest fungicides, management of fruit age, and ripening at controlled temperatures.

For effective and realistic rot control to be achieved in the market place there needs to be a suite of tools to handlers and growers that reduces inoculum load, sustains and enhances fruit and tree health, and optimises the orchard and postharvest environments.

SELECTED REFERENCES

Coates, L.M., Irwin, J.A.G. and Muirhead, I.F. (1993). The use of a benomyl-resistant mutant to demonstrate latency of *Colletotrichum gloeosporioides* in avocado fruit. *Australian Journal of Agricultural Research* **44**: 763-772.

Cooke, T. and Coates, L. (1994). Anthracnose- field control is essential. *Scientific Research and Technical Supplement No.* **20**: 48-50

Darvas, J.M. (1982). Etiology and control of some fruit diseases of avocado (*Persea americana* Mill.) at Westfalia Estate. D.Sc. (Agric.) thesis. University of Pretoria, South Africa. 136pp.

Dixon, J. (2001). Development of fruit quality disorders in New Zealand avocados at outturn in the USA for the 2000-2001 and 2001-2002 seasons. *New Zealand Avocado Growers Association Annual Research Report* **1**: 31-40

Dixon, J. and Pak, H.A. (2002). Analysis of packhouse library tray data from 2001/2002 season. *New Zealand Avocado Growers' Association Annual Research Report Volume* **2**:

Everett, K.R. (1994). Isolation and testing of fungi from three shelter belt species (*Casuarina cunninghamiana, Cryptomeria japonica* and *Salix* sp.) adjacent to two avocado orchards. *HortResearch Client Report No. 94/123*.

Everett, K.R. (1999a). Orchard survey: effect of pre-harvest factors on postharvest rots. *HortResearch Client Report No. 1999/266*.

Everett, K.R. (2000a). Testing the effectiveness of TBZ (thiabendazole) against avocado body rots. *HortResearch Client Report No. 2001/4*.

Everett, K.R. (2000b). Orchard survey: effect of pre-harvest factors on postharvest rots. Part II. *HortResearch Client Report No. 2001/ 209*.

Everett, K.R. (2001a). Orchard fungicide trial. *HortResearch Client Report No. 2001/388*

Everett, K.R. (2001b). Orchard survey: effect of pre-harvest factors on postharvest rots. Part III. Final Report to Avocado Industry Council. *HortResearch Client Report No. 2002/208*.

Everett, K.R. (2002) Consultancy services. *HortResearch Client Report No. 2002/253*.

Everett, K.R. and Chynoweth, R. (2002a). Disease Progress Curves. *HortResearch Client Report No. 2002/418*.

Everett, K.R. and Chynoweth, R. (2002b). Infection Criteria. *HortResearch Client Report No. 2003/28.*

Everett, K.R. and Hallett, I.C. (1997). Is *Colletotrichum acutatum* an important pathogen of 'Hass' avocado in New Zealand**?** Abstract 306 In: *Proceedings Australasian Plant Pathology Society Conference* Sept 29-Oct 3 Perth.

Everett, K.R. and Pak, H.A. (2001). Orchard survey: effect of pre-harvest factors on postharvest rots. *New Zealand Avocado Growers Association Annual Research Report* **1**:12-17

Everett, K.R. and Stevens, P.S. (1998). Factors affecting fruit set in avocados - Insects and fungi in flowers. *HortResearch Client Report No. 98/135*.

Everett, K.R., Hallett, I.C., Yearsley, C. Lallu, N. and Rees-George, J. (2001). Lenticel damage. *HortResearch Client Report No. 2001/280*.

Hartill, W.F.T. (1987). Post-harvest rots of avocados and orchard practices. Results of a survey in the 1986-87 season. *Report to the New Zealand Avocado Promotion Association Inc*.

Hartill, W.F.T. (1988a). Effects of avocado fruit maturity on susceptibility to post-harvest rots. *Report to the New Zealand Avocado Promotion Association Inc*.

Hartill, W.F.T. (1989a). Report to the avocado promotion research committee on the relationship between post-harvest rots and fungal pathogens present in ring-neck necrotic scars.

Hartill, W.F.T. (1989b). Report to the avocado promotion research committee on the fungal ecology of dead branches and twigs of avocado trees.

Hartill, W.F.T. (1989c). Report to the avocado promotion research committee on the relationship between time of harvesting and severity of post-harvest rots.

Hartill, W.F.T. (1989d). Disinfectant dips to control post-harvest rots in avocados. *Scientific Research and Technical Supplement* No. 4: 6-8.

Hartill, W.F.T. (1989e). Investigation into the effect of brushing on avocado fruit and subsequent development of post-harvest rots. *Scientific Research and Technical Supplement* No. 4: 9.

Hartill, W.F.T. (1991a). Post-harvest diseases of avocado fruit in New Zealand. *New Zealand Journal of Crop and Horticultural Science* **19**: 297-304.

Hartill, W.F.T. (1991b). Report to the avocado growers research committee on a comparison of sodium hypochlorite and benomyl with prochloraz for post-harvest rot control in avocados.

Hartill, W.F.T. (1993). Distribution of fruit rot pathogens in twigs and branches of avocado trees. *HortResearch Client Report No. 93/23*.

Hartill, W.F.T. (1995). An investigation of the mode of entry of pathogens causing neck rots in ripening avocados. II. Disinfestation of secateurs. *HortResearch Client Report No. 95/6*.

Hartill, W.F.T. and Everett, K.R. (1997). An investigation of the mode of entry of pathogens causing post-harvest rots in ripening avocados. III. Effect of different harvesting techniques. *HortResearch Client Report No. 97/51*.

Hartill, W.F.T. and Everett, K.R. (2002). The effect of harvesting techniques on the incidence of stem-end rots. *HortResearch Client Report No. 2002/346*.

Hartill, W.F.T. and Sale, P.R. (1990). The effects of combining Benlate and Sportak in fungicide dips to control post harvest rots in avocados. *Scientific Research and Technical Supplement* No. 7: 8.

Hartill, W.F.T. and Sale, P.R. (1991a).A comparison of disinfectants (sodium hypochlorite and potassium permanganate) with prochloraz for postharvest rot control in avocados. *Scientific Research and Technical Supplement* No. 11: 10.

Hartill, W.F.T. and Sale, P.R. (1995b). A comparison of Foli-R-Fos, Foli-R-Fos mixed or alternated with Benlate, and Kocide spray treatments for the control of post-harvest rots of avocados. *HortResearch Client Report No. 95/08*.

Hartill W.F.T. and Yearsley, C.W. (1989). The influence of controlled atmospheres during storage and ripening on the development of postharvest rots. *A report to the Avocado Promotion Research Committee*.

Hartill, W.F.T., Everett, K.R. and Pak, H.A. (2002). Stem-end rots: the infection portal. *New Zealand Avocado Growers Association Annual Research Report* **2**:

Hartill, W.F.T., Everett, K.R. and Sale, P.R. (1994). A comparison of Aliette, Foli-R-Fos, and Kocide spray treatments for the control of post-harvest rots of avocados- 1994 harvest. *HortResearch Client Report No.94/12*.

Hartill, W.F.T., Everett, K.R., Sale, P.R. and Sawden, D. (1992). Report to the avocado growers research committee on the effects of Kocide and Benlate sprays, dead wood removal, and post-harvest dipping in Sportak on the incidence of post-harvest rots.

Hartill, W.F.T., Fowler, M., Sale, P.R. and Sawden, D.S. (1990). The effect of copper sprays and dead wood removal on the incidence of postharvest rots. *Scientific Research and Technical Supplement* No. 7: 4-6.

Hartill, W.F.T., Everett, K.R. and Sale, P.R. (1994a). A comparison of sodium hypochlroite and Benlate with Sportak for postharvest rot control in avocados. *Scientific Research and Technical Supplement* No. 19: 7-9.

Hartill, W.F.T., Sale, P. and Sawden, D. (1989). Orchard management and post harvest rots. Spray trial and dead wood removal- progress report and results of assessments. *Scientific Research and Technical Supplement* No. 4: 3-6.

Hopkirk, G., Cregoe, B.A. and Yearsley, C.W. (1990). The effect of temperature on postharvest quality of New Zealand avocados. *Report to the New Zealand Avocado Promotion Association Inc*.

Hopkirk, G., White, A., Forbes, S.K. and Beever, D.J. (1991). Postharvest handling of avocados and fruit quality- research results for 1991. *Scientific Research and Technical Supplement* No. 11: 11-14.

Hopkirk, G., White, A., Beever, D.J. and Forbes, S.K. (1994). Influence of postharvest temperatures and the rate of ripening on internal postharvest rots and disorders of New Zealand 'Hass' avocado fruit. *New Zealand Journal of Crop and Horticultural Science* **22**: 305-311.

Lallu, N., Yearsley, C., Burdon, J., Billing, D., Punter, M. and Osman, S. (2002). Effects of handling temperatures, and airflows during storage or shipping, on shelf life quality of Hass avocados. *HortResearch Client Report No. 2003/64*.

Milne, D.L. (1998). Avocado quality assurance: Who? Where? When? How? *South African Avocado Growers Association Yearbook* **21**: 39-47.

Johnston, J. and Banks, N.H. (1996). Weight loss of harvested avocados. Final report for 1996 prepared for the NZ Avocado Industry Council. Centre for Postharvest and Refrigeration Research. Massey University.

Pak, H.A. (2001). Pattern of disease development in late season fruit. *New Zealand Avocado Growers Association Annual Research Report* **1**: 54-56

Pennycook, S.R. (1985). Fungal fruit rots of *Actinidia deliciosa* (kiwifruit). *New Zealand Journal of Experimental Agriculture* **13**: 289-299.

Peterson, R.A. (1978). Susceptibility of Fuerte avocado fruit at various stages of growth to infection by anthracnose and stem-end rot fungi. *Australian Journal of Experimental and Animal Husbandry* **18**: 158-160.

Prusky, D., Plumbley, R.A. and Kobiler, I. (1991). The relationship between antifungal diene levels and fungal inhibition during quiescent infection of unripe avocado fruits by *Colletotrichum gloeosporioides*. *Plant Pathology* **40**: 45-52.

Sale, P. (1993). Progress in the control of postharvest rots. *Scientific Research and Technical Supplement* No. 18: 9-16.

Spalding, D.H. and Reeder, W.F. (1975). Low-oxygen high-carbon dioxide controlled atmostphere storage for control of anthracnose (*Colletorichum gloeosporiodies*) and chilling injury of avocados. *Phytopathology* **65**: 458-460.

White, A. and Forbes, S. (1994). Summary of Postharvest avocado research undertaken by DSIR and HortResearch. *HortResearch Client Report No. 94/297*.

White, A., Woolf, A.B. and Burdon, J.N. (1996). Avocado postharvest research programme 1995/96. *HortResearch Client Report No. 96/82*.

White, A., Forbes, S., Hopkirk, G. and Beever, D. (1993). Postharvest handling of avocados and fruit quality research results for 1993. *Scientific Research and Technical Supplement* No. 17: 15-16.

White, A., Woolf, A.B., Cox, K., Everett, K. R. and Davy, M. (1999). Avocado Postharvest Research 1998/99 - Novel Postharvest Treatments for Rot Control. Report to the NZ Avocado Industry Council. *HortResearch Client Report No. 1999/300*.

Woolf, A.B., McLeod, D.L., Roughan, S., Yearsley, C.W. and Burdon, J.N. (1997a). Postharvest research 1996/97: Effect of snap picking on fruit quality and shelf life. *HortResearch Client Report No. 97/52*.

Woolf, A.B., McLeod, D.L., Roughan, S., Burdon, J.N. and White, A. (1997b). Avocado postharvest research: 1996/97 Ethylene ripening protocosl for local and export market avocados. *HortResearch Client Report No. 97/118*.

Woolf, A.B., Jamieson, L.E., Whiting, D.C., McDonald, R.M., Connolly, P.G., Davy, M., Cox, K., Stevenson, B. and White, A. (1999). Water-blasting avocados postharvest for the enhancement of export and domestic market value by the removal of surface contaminants including insect pests. *HortResearch Client Report No. 2000/7652*.