Field evaluation of fungicides to control postharvest rots of avocados in New Zealand

K.R. Everett, H.A. Pak, I.P.S. Pushparajah, J.T. Taylor, M.S. Astill, D.B. King and A. Ah Chee

The New Zealand Institute for Plant & Food Research Limited, Private Bag 92169, Mt Albert, Auckland 1142, New Zealand

Corresponding author: Kerry.Everett@plantandfood.co.nz

Abstract Copper is the only fungicide currently registered for use on avocado orchards for controlling fruit rots that are expressed postharvest. Two additional fungicides that performed well in previous tests were evaluated as spray applications to 12 orchards, four in each of the three major avocado growing regions of New Zealand (North of Kaitia, Whangarei and Bay of Plenty). Pyraclostrobin/boscalid and fluazinam were at least as effective as copper in controlling avocado rots, and are suitable alternatives to copper. Fluazinam should be applied in winter because in combination with the additive di-1-p-methene it damaged leaves during the spring flush. Pyraclostrobin/boscalid would need to be used judiciously to prevent build up of resistance in fungal populations. Copper could still be applied, but in combination with these fungicides, thus reducing the numbers of applications of copper and therefore the risk of copper accumulation in soil.

Keywords fluazinam, boscalid/pyraclostrobin, body rots, stem-end rots.

INTRODUCTION

'Hass' is the most common avocado (*Persea americana* Mill.) cultivar grown in New Zealand. This variety is susceptible to fruit rots that infect through the cut stem at harvest (Hartill & Everett 2002) (stem-end rots) or through the side of the fruit (body rots). In New Zealand the two symptoms are caused by several fungi (Hartill 1991), of which the most common is *Botryosphaeria parva*, followed, in order of importance, by *Colletotrichum acutatum*, *B. dothidea*, *C. gloeosporioides* and *Phomopsis* sp. (Everett et al. 2007).

Avocado fruit harvested from orchards throughout the main growing regions of New Zealand and stored at 20°C were severely affected by rots (Everett et al. 2007). However, during

the course of a 3-year study the incidence of rots declined from 48% to 27% concomitant with an increase in the number of fungicides (either copper or benomyl) that were applied. Benomyl has since been withdrawn from the market, and copper was the only fungicide registered for use on avocado orchards in New Zealand. Trials have shown that at least eight applications of copper per season are required for effective control, with some growers applying as many as 15 in a season (Everett et al. 2007). Frequent use of copper can cause a build-up of residues in the soil that has been shown to detrimentally affect earthworms. Earthworms are essential for good soil health (Zwieten et al. 2004). Although copper is not biodegradable, in orchards in New

Zealand levels are generally below those regarded as toxic (Holland & Solomona 1999; Pak et al. 2009). However, provision of biodegradable fungicides as effective at controlling avocado rots as copper would mitigate the possibility of residues reaching toxic levels.

Laboratory screening has identified two fungicides (fluazinam and pyraclostrobin/boscalid) that showed potential for controlling avocado rots. The effective concentration at which 50% of spore germination and mycelial growth was inhibited (EC_{50}) was very low for both pyraclostrobin/boscalid (Everett & Timudo-Torrevilla 2007) and fluazinam (Everett et al. 2005). These fungicides have been tested in limited field trials (Everett et al. 2005, 2008). In the first field trial, fluazinam did not control postharvest rots (Everett et al. 2005). However, in the second field trial the wetter/spreader di-1-p-methene was added to fluazinam at the highest recommended rate, and in this trial there was significant reduction of body rots when fruit were sprayed with this treatment eight times during the season (Everett et al. 2008).

The most important avocado growing regions in New Zealand, the Far North, Whangarei and Bay of Plenty, range in latitude from 38° to 35°S. Climate and soil type differ between the three regions. Temperature affects the incidence of rots (Everett et al. 2007), and because of these differences fungicides may vary in effectiveness between these three regions. This study evaluated the efficacy of two new fungicides, as an alternative to copper, for controlling postharvest rots of avocados in the three major avocado growing regions of New Zealand during the 2008/09 season.

MATERIALS AND METHODS

Fungicide application

Twelve orchards with trees that were about 5 years old were selected from the three main avocado growing regions, four each from the Far North (North of Kaitia), Whangarei and Bay of Plenty (Te Puke and Katikati). In each orchard 20 trees in a discrete block were marked. Four treatments were ascribed in a completely randomised block design with five tree replicates.

The treatments were: (1) pyraclostrobin/boscalid, (2) fluazinam + di-1-p-methene, (3) copper hydroxide and (4) unsprayed control, and the chemicals were applied at the rates described in Table 1.

Treatments were applied to the point of run-off using a pressurised hand gun sprayer at approximately 8 litres/tree. Spray applications were applied at monthly intervals (Table 2) and where possible on fine calm days to minimise spray drift between treatments (Everett 2002; Everett et al. 2007). In the Bay of Plenty fluazinam was applied without di-1-p-methene for the October application due to phytotoxic damage of new leaves in the fluazinam + di-1-p-methene treatment. Fruit were harvested on 3 and 4 November (Far North), 11 and 12 November (Whangarei) and 18 and 19 November 2008 (Bay of Plenty), and 100 fruit per treatment per orchard, a total of 4800 fruit, were collected for assessment.

Fruit evaluation

Harvested fruit were placed in avocado trays (20 fruit per tray), stored at 5°C for 28 days, and evaluated following ripening at 20°C. Once ripe, as determined by gentle hand squeezing, fruit

Table 1 Application rates of products tested as spray applications for control of avocado fruit rots.

Fungicide product	Active ingredient	Chemical group	Rate applied (g or ml ai/100 litres)
Pristine®	pyraclostrobin/boscalid	strobilurin/ carboxamide	7.7/15.2 g
Kocide® Opti	copper hydroxide	copper	27 g
Shirlan®	fluazinam	pyridinamine	50 ml
Nufilm™-17	di-1-p-methene	terpene polymer	115.2 ml

Table 2 Dates on which spray treatments were applied to trees in the Far North, Whangarei and Bay of Plenty.

Application number	Far North	Whangarei	Bay of Plenty
1	18/3/2008	17/3/2008	6/3/2008
2	12/4/2008	10/4/2008	8/4/2008
3	24/4/2008	5/6/2008	7/5/2008
4	20/6/2008	19/6/2008	10/6/2008
5	28/7/2008	30/7/2008	8/7/2008
6	2/9/2008	29/8/2008	21/8/2008
7	29/9/2008	1/10/2008	17/9/2008
8	29/10/2008	28/10/2008	14/10/2008

were cut in quarters and peeled. Body rots and stem-end rots were scored separately using a 0-100 rating scale (Everett & Korsten 1996). The results are presented as proportion of fruit with rots out of 100 (incidence).

Statistical analysis

Results were analysed using the General Linear Model (analysis of variance) of MINITAB® (version 15.0). Region, orchard, tree and fruit were included as factors. Orchard and region were co-variables. Regions were compared using Tukey's test ($\alpha < 0.05$). For each orchard, means were separated using Dunnett's one-tailed test ($\alpha < 0.05$) in which all treatments were compared with the untreated control. Tukey's test was also performed to determine if there was any difference between fungicides. Incidence data were square root arcsine transformed before analysis.

RESULTS

There was a significant regional effect on the incidence of both body rots and stem-end rots ($P < 0.01$) when a multi-factorial analysis of variance was performed using region, treatment and tree as factors. When region and orchard were included as co-variables the orchard effect was more significant than the regional effect. The interactions between the other factors were not significant. A significantly higher proportion of fruit from Whangarei was affected by stem-end rots compared with fruit from the other

two regions ($P < 0.005$). A significantly lower proportion of fruit from the Far North was affected by body rots than fruit from the other two regions ($P < 0.01$).

Overall, pyraclostrobin/boscalid and fluazinam controlled body rots at least as well as copper (Table 3), and pyraclostrobin/boscalid was more effective ($P < 0.05$, Figure 1). The incidence of body rots was lowered by pyraclostrobin/boscalid treatments on all the experimental sites, but copper failed to significantly reduce the incidence of body rots on four orchards, and fluazinam did not reduce its incidence on three orchards.

Stem-end rots were controlled more effectively by pyraclostrobin/boscalid than by copper and fluazinam. Overall, only fruit treated with pyraclostrobin/boscalid had significantly fewer stem-end rots than the untreated control fruit ($P < 0.005$, Figure 1). On one Far North orchard (orchard no. 3), fruit treated with fluazinam had significantly more stem-end rots than the untreated control (Table 4). The incidence of stem-end rots was significantly reduced on six orchards by pyraclostrobin/boscalid, on two orchards by fluazinam, and on three orchards by copper hydroxide (Table 4).

DISCUSSION

In a survey of orchards conducted during 1999-2001, average body rot incidence for each of the 3 years the orchards were studied ranged from 21.3 to 6.5% and stem-end rots from 16.3

Figure 1 Mean incidence of (a) body rots and (b) stem-end rots for fruit from 12 orchards from the three major avocado growing districts of New Zealand (Far North, Whangarei and Bay of Plenty). The fruit was treated with fungicides applied as an orchard spray or left untreated. Different letters represent values that are significantly less than untreated controls according to Dunnett's one-tailed test ($P < 0.05$). Data were square root arcsine transformed before analysis then back transformed.

to 41% (Everett et al. 2007). In this present study the incidence of rots was slightly higher. This difference is probably due to the different harvest dates – the fruit in the orchard survey were harvested in January whilst the fruit in the current study were harvested in November. Although the storage conditions were different, (the fruit in the survey were stored and ripened at 20°C) it has been shown that this has no significant effect on rot incidence (Everett 2003).

The three fungicides shown to be effective at reducing postharvest rots of avocado in this present study are more biodegradable than copper. Fluazinam has a half-life in soil of 30 days (Giles-Parker 2001; Dong et al. 2008), pyraclostrobin of 8-55 days (Anonymous 2004) and boscalid of less than 2 weeks (Giles-Parker 2003). Pyraclostrobin has a single site mode of action and although its formulation in combination with boscalid, which is a

Table 3 The incidence (proportion out of 100 fruit) of body rots in avocado fruit after treatment with fungicides in 12 different orchards from three growing regions in 2008. Values are mean $\pm$ standard error.

Orchard	pyraclostrobin/ boscalid	fluazinam	copper hydroxide	untreated
Far North				
1	0.13 $\pm$ 0.06 * ¹	0.39 $\pm$ 0.06 ns	0.35 $\pm$ 0.10 ns	0.50 $\pm$ 0.13
2	0.05 $\pm$ 0.02 *	0.14 $\pm$ 0.04 *	0.17 $\pm$ 0.06 *	0.41 $\pm$ 0.11
3	0.11 $\pm$ 0.03 *	0.11 $\pm$ 0.06 *	0.26 $\pm$ 0.06 ns	0.36 $\pm$ 0.11
4	0.21 $\pm$ 0.06 *	0.35 $\pm$ 0.08 ns	0.27 $\pm$ 0.07 *	0.51 $\pm$ 0.05
Whangarei				
5	0.28 $\pm$ 0.08 *	0.53 $\pm$ 0.11 *	0.23 $\pm$ 0.04 *	0.73 $\pm$ 0.05
6	0.28 $\pm$ 0.06 *	0.25 $\pm$ 0.03 *	0.40 $\pm$ 0.07 ns	0.61 $\pm$ 0.14
7	0.19 $\pm$ 0.06 *	0.37 $\pm$ 0.09 *	0.43 $\pm$ 0.10 *	0.74 $\pm$ 0.06
8	0.17 $\pm$ 0.09 *	0.26 $\pm$ 0.07 *	0.36 $\pm$ 0.02 *	0.60 $\pm$ 0.08
Bay of Plenty				
9	0.18 $\pm$ 0.04 *	0.12 $\pm$ 0.04 *	0.27 $\pm$ 0.05 *	0.50 $\pm$ 0.04
10	0.15 $\pm$ 0.04 *	0.16 $\pm$ 0.04 ns	0.19 $\pm$ 0.06 ns	0.35 $\pm$ 0.09
11	0.36 $\pm$ 0.13 *	0.40 $\pm$ 0.04 *	0.33 $\pm$ 0.05 *	0.72 $\pm$ 0.09
12	0.30 $\pm$ 0.12 *	0.50 $\pm$ 0.16 *	0.46 $\pm$ 0.06 *	0.86 $\pm$ 0.03

¹Significance of differences: *=values are significantly less than untreated controls according to Dunnett's one-tailed test ($P < 0.05$). Data were square root arcsine transformed before analysis then back transformed; ns=not significant.

Table 4 The incidence (proportion out of 100 fruit) of stem-end rots of avocado fruit after treatment with fungicides in 12 orchards from three different growing regions in 2008. Values are mean $\pm$ standard error.

Orchard	pyraclostrobin/ boscalid	fluazinam	copper hydroxide	untreated
Far North				
1	0.20 $\pm$ 0.11 ns ¹	0.46 $\pm$ 0.12 ns	0.34 $\pm$ 0.15 ns	0.36 $\pm$ 0.12
2	0.08 $\pm$ 0.03 *	0.18 $\pm$ 0.05 ns	0.12 $\pm$ 0.08 *	0.37 $\pm$ 0.12
3	0.10 $\pm$ 0.04 ns	0.29 $\pm$ 0.03 #	0.08 $\pm$ 0.02 ns	0.15 $\pm$ 0.05
4	0.16 $\pm$ 0.07 ns	0.26 $\pm$ 0.08 ns	0.22 $\pm$ 0.01 ns	0.30 $\pm$ 0.08
Whangarei				
5	0.16 $\pm$ 0.03 *	0.36 $\pm$ 0.09 ns	0.20 $\pm$ 0.07 *	0.44 $\pm$ 0.05
6	0.38 $\pm$ 0.07 *	0.34 $\pm$ 0.07 *	0.51 $\pm$ 0.02 ns	0.61 $\pm$ 0.09
7	0.30 $\pm$ 0.09 *	0.48 $\pm$ 0.09 ns	0.57 $\pm$ 0.04 ns	0.61 $\pm$ 0.09
8	0.17 $\pm$ 0.05 *	0.22 $\pm$ 0.08 ns	0.45 $\pm$ 0.06 ns	0.40 $\pm$ 0.09
Bay of Plenty				
9	0.16 $\pm$ 0.04 *	0.21 $\pm$ 0.04 ns	0.28 $\pm$ 0.03 ns	0.30 $\pm$ 0.04
10	0.20 $\pm$ 0.04 ns	0.15 $\pm$ 0.05 ns	0.26 $\pm$ 0.06 ns	0.14 $\pm$ 0.03
11	0.29 $\pm$ 0.11 ns	0.15 $\pm$ 0.03 *	0.32 $\pm$ 0.06 ns	0.44 $\pm$ 0.09
12	0.39 $\pm$ 0.06 ns	0.33 $\pm$ 0.10 ns	0.21 $\pm$ 0.05 *	0.56 $\pm$ 0.10

¹Significance of differences: *=values are significantly less than untreated controls according to Dunnett's one-tailed test ($P < 0.05$). Data were square root arcsine transformed before analysis then back transformed; ns=not significant; #= values are significantly greater than untreated controls according to Dunnett's one-tailed test ($P < 0.05$).

broad spectrum fungicide, reduces the risk of resistance developing in fungal populations, it is recommended to be used 2-3 times in a programme that includes other fungicides (Hauke et al. 2004). Fluazinam in combination with di-1-p-methene was observed to damage leaves during the spring flush, and for this reason should only be applied during winter and possibly late summer.

Once registered for use on avocados pyraclostrobin/boscalid and fluazinam could be used in combination with copper to reduce the total number of copper applications required to control avocado rots. In an orchard survey it was found that the number of fungicide applications is 6-9 times in a season for best rot control (Everett 2002). Copper in soils can become a problem if the concentration becomes higher than 500 parts per million (ppm) (Holland & Solomona 1999). Copper can persist in the soil and values as high as 1030 ppm have been reported in vineyards in France (Komarek et al. 2010). In avocado growing regions in New Zealand the highest concentration of copper found in soils was one orchard at 541 ppm (Pak et al. 2009), but the median was 68 ppm. If these other fungicides are used instead of copper for 3-4 spray applications in a season, then the possibility of copper residues reaching higher values than 500 ppm is reduced, or at least extended further into the future.

In conclusion, pyraclostrobin/boscalid and fluazinam are suitable alternatives to field applications of copper fungicides for controlling avocado fruit rots, at least until November. The removal of di-1-p-methene from sprays applied in the Bay of Plenty in October reduced phytotoxicity damage to leaves on those orchards. Fluazinam would be most usefully applied during winter when there was least risk of damaging leaves. A replicated spray trial would need to be carried out to investigate if application of fluazinam alone provides effective rot control and does not damage leaves. Although pyraclostrobin/boscalid was more effective than copper when applied eight times during the season, that product would need to be used judiciously to prevent build-up of resistance in

fungal populations. Copper could still be applied in combination with these fungicides, thus reducing the numbers of applications of copper, and therefore the impact of this fungicide on the environment and as part of a fungicide resistance management strategy.

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REFERENCES

- Anonymous 2004. Review report for the active substance pyraclostrobin. European Commission Health & Consumer Protection Directorate-General, Commission working document <http://ec.europa.eu/food/plant/protection/evaluation/newactive/pyraclostrobin.pdf> (accessed 23 June 2011).
- Dong F, Yang S, Liu X, Sun J, Zheng Y, Li C, Yao J 2008. Fate of fluazinam in pepper and soil after application. *Agricultural Sciences in China* 7: 193-199.
- Everett KR 2002. Avocado fruit rots: A review of industry funded research. New Zealand Avocado Growers' Association Annual Research Report 2: 8-16.
- Everett KR 2003. The effect of low temperatures on *Colletotrichum acutatum* and *Colletotrichum gloeosporioides*, fungi causing body rots of avocado in New Zealand. *Australasian Plant Pathology* 32: 441-448.
- Everett KR, Korsten L 1996. Postharvest rots of avocados: improved chemical control by using different application methods. *Proceedings of the 49th New Zealand Plant Protection Conference*: 37-40.
- Everett KR, Timudo-Torrevilla OE 2007. *In vitro* fungicide testing for control of avocado fruit rots. *New Zealand Plant Protection* 60: 99-103.
- Everett KR, Owen SG, Cutting JGM 2005. Testing efficacy of fungicides against postharvest pathogens of avocado (*Persea americana* cv. Hass). *New Zealand Plant Protection* 58: 89-95.

- Everett KR, Boyd LM, Pak HA, Cutting JGM 2007. Calcium, fungicide sprays and canopy density influence postharvest rots of avocado. *Australasian Plant Pathology* 36: 22-31.
- Everett KR, Timudo-Torrevilla OE, Hill GN, Dawson TE 2008. Field testing alternatives to copper for controlling avocado fruit rots. *New Zealand Plant Protection* 61: 65-69.
- Giles-Parker C 2001. Fluazinam. Pesticide Fact Sheet, United States Environmental Protection Agency. <http://www.epa.gov/opprd001/factsheets/fluazinam.pdf> (accessed 23 June 2011).
- Giles-Parker C 2003. Boscalid. Pesticide Fact Sheet, United States Environmental Protection Agency. <http://www.epa.gov/opprd001/factsheets/boscalid.pdf> (accessed 23 June 2011).
- Hartill WFT 1991. Post-harvest diseases of avocado fruits in New Zealand. *New Zealand Journal of Crop and Horticultural Science* 19: 297-304.
- Hartill WFT, Everett KR 2002. Inoculum sources and infection pathways of pathogens causing stem-end rots of 'Hass' avocado (*Persea americana*). *New Zealand Journal of Crop and Horticultural Science* 30: 249-260.
- Hauke K, Creemers P, Brugmans W, Laer Sv 2004. Signum, a new fungicide with interesting properties in resistance management of fungal diseases in strawberries. *Communications in Agricultural and Applied Biological Sciences* 69: 743-755.
- Holland P, Solomona S 1999. Copper status of orchards. *The Orchardist* 72: 44-45.
- Komarek M, Cadkova E, Chrastny V, Bordas F, Bollinger JC 2010. Contamination of vineyard soils with fungicides: a review of environmental and toxicological aspects. *Environment International* 36: 138-151.
- Pak HA, Elmsly TA, Everett KR 2009. Beyond AvoGreen. 4th Australian and New Zealand Avocado Growers Conference (ANAZGC09). 21-24 July www.avocadosource.com (accessed 23 June 2011).
- Zwieten Lv, Rust J, Kingston T, Merrington G, Morris S 2004. Influence of copper fungicide residues on occurrence of earthworms in avocado orchard soils. *Science of the Total Environment* 329: 29-41.