SEEKING A POST-HARVEST FUNGICIDE SUITABLE FOR THE USA MARKET FOR LATE SEASON 'HASS' AVOCADO FRUIT

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ABSTRACT

Avocados harvested in the late season, November to January, are not currently exported to the USA as they are likely to develop unacceptable levels of ripe rots in the market. Treatments that help to maintain fruit quality and reduce the expression of ripe rots could allow the option to export fruit to the USA in the late season. Further, such treatments could assist in extending the marketing window thereby helping with crop flow programmes and be used to extend storage durations allowing the development of new, distant markets. Prochloraz can not be used as a post-harvest fungicide for fruit exported to the USA because prochloraz residues are not allowed in the USA. An alternative fungicide, as effective at controlling ripe rots as prochloraz would be useful to help maintain fruit quality. Any alternative fungicide needs to be applied at a concentration that does not result in residues exceeding the MRL level set in the USA. The effectiveness of five fungicides identified in consultation with chemical suppliers as having potential to control ripe rots of late season 'Hass' avocado fruit was investigated. Carbendazim, azoxystrobin, folpet, fatty acids (potassium salts) and benomyl were evaluated and results compared to prochloraz and water dipped control. All fungicide treatments were ineffective in controlling ripe rots. Therefore, none of the fungicides tested would have merit to mitigate ripe rots in late season 'Hass' avocado fruit exported to the USA.

Keywords: *carbendazim, azoxystrobin, folpet, fatty acids (potassium salts), benomyl, prochloraz, fruit quality, ripe rots*.

INTRODUCTION

'Hass' Avocado fruit are exported from New Zealand to distant markets from October to March. As the harvest season progresses the fruit harvested late in the season, March to April, typically develops more ripe rots than fruit harvested in the middle of the season, November to January (Dixon *et al.,* 2003). Fruit exported to distant markets such as the USA can be susceptible to developing ripe rots as the fruit can take longer than three weeks from harvest to sale. Avocados harvested in the late season are not currently exported to the USA as they are likely to develop unacceptable levels of ripe rots in the market. Treatments that help to maintain fruit quality and reduce the expression of ripe rots could allow the option to export fruit to the USA in the late season. Further, such treatment could assist in extending the marketing window thereby helping with crop flow programmes and be used to extend storage durations allowing the development of new, distant markets.

In New Zealand avocados, postharvest ripe fruit rots are caused by a complex of five fungi: *Colletotricum gloeosporioidies, Colletotricum acutatum, Botryosphaeria parva, Botryosphaeria dothidea* and *Phomopsis* spp. commonly referred to by their location on the fruit as either body rots or stem-end rots (Everett and Pak, 2001). There has been a number of novel treatments investigated to control these rots with low or no chemical residues present on treated fruit. The treatments include: chlorine dioxide (EnviroXyde™) and bromo-chloro dimethyl hydantonin (Nylate™) (Dixon *et al.,* 2004), modified atmosphere (Dixon *et al.,* 2003), Dynamic Controlled Atmosphere (Yearsley *et al.,* 2003), fruit coating Alobua™ FC-12 (Dixon *et al.,* 2005), low pH dips, CO_2 shock and UV-C radiation (Lallu *et al.,* 2003). None of these treatments were successful in reducing ripe rots. Post-harvest dipping of prochloraz (Sportak®) is the currently accepted treatment for fruit sent to the Australian market for control of ripe rots (Dixon *et al.,* 2003). A number of trials have shown an efficacy of between 50 to 60% for prochloraz when fruit are dipped immediately after harvest (Le Roux *et al.,* 1985; Everett, 2002). Prochloraz can not be used as a post-harvest fungicide for fruit exported to the USA because prochloraz residues are not allowed in the USA. An alternative fungicide, as effective at controlling ripe rots as prochlroraz would be useful to help maintain fruit quality. Any alternative fungicide needs to be applied at a concentration that does not result in residues exceeding the MRL level set in the USA. The effectiveness of five fungicides identified in consultation with chemical suppliers as having potential to control ripe rots of late season 'Hass' avocado fruit was investigated.

MATERIALS AND METHODS

Late season 'Hass' avocado fruit from two commercial orchards in the Western Bay of Plenty (37°S, 176°E) were commercially harvested on the 26th of March 2007 and placed into cool storage at 5°C. Twenty-four hours after harvest, the fruit were graded in a commercial packing facility according to local market requirements. Fruit weighing between 162g and 270g were placed into F40 crates 20 to 30 at a time and dipped into a 50 litre bin containing fungicide for two minutes. The fungicide solution was vigorously agitated using a paint stirrer mounted on a high speed electric drill. After dipping, the fruit were drained for about one minute then placed on racks to dry at ambient for about 30 minutes. When dry, fruit were packed into single layer trays on moulded pulp liners. Fruit were stored for 28 days from harvest at 5°C ± 0.5°C, RH 90% ± 5%. All fruit were ripened at 20°C ± 1°C, RH 57% ± 5%. Once the fruit reached at least a minimum eating softness, determined by hand feel equivalent to a firmometer measurement of 85 with a 300g weight, the fruit were then assessed for external and internal fruit quality disorders according to the Avocado Industry Council Fruit Assessment Manual (Dixon, 2003).

The fungicides were evaluated in a randomised block design where 5 replicates of 20 fruit per treatment were dipped in the fungicides listed in Table 1. The efficacy of the fungicides to control ripe rots was compared to prochloraz and water dip controls. Concentrations of azoxystrobin and folpet were determined by calculating the residue likely to be present immediately after drying that was approximately equal to 20 % of the MRL set for the USA (Table 1). Carbendazim, benomyl and fatty acids (potassium salts) dip concentrations were the label rates for recommended by chemical suppliers. Prochloraz, was applied at label rate for post-harvest dipping of avocados of 55ml per 100 litres.

Once the fruit were dry, three samples of 10 fruit were taken from each treatment for residue testing.

Table 1. Fungicide and control treatments investigated.

Treatment	Active ingredient	USA MRL	Rate used (per 100L)
MBC® 800WDG	Carbendazim		50g
Amistar® WG	Azoxystrobin	2.00	22g[1]
Folpan™	Folpet	25.00	128g[1]
Elliot Protector®	Fatty acids (potassium salts)	GRAS[3]	1000ml
Benlate®	Benomyl	3.00[2]	50g
Sportak®	Prochloraz	None set	55ml
Water Dip			

[1] Rate calculated to archive a residue equal to 20% of the USA MRL. [2] Expires 1st Jan 2008. [3] Generally Recognised As Safe.

Three 60ml samples of the dip solution, one before dipping, one during and one after dipping were collected to analyse fungicide concentration and calculate stripping rate. All samples were tested using liquid chromatography mass spectroscopy or a gas chromatograph-mass spectrometer for fungicide residues in a commercial testing laboratory (Hill Laboratories, Hamilton)

Fruit dry matter content at harvest was measured using a 20 fruit sample from each orchard, using the method described by Mandemaker (2004). Fruit dry matter content was 35.2% for orchard A and 37.7% for orchard B.

Results were analysed by One-Way ANOVA using Tukeys' family error rate of 5% using MINITAB version 13.31.

RESULTS

There was no difference in green and ripe fruit quality between the two orchards investigated. Green fruit disorders, fuzzy patches and discrete patches, were similar between treatments (data not shown). Fruit quality was poor, with 50% of the water dipped fruit with some stem end rot and 87.5% having some body rots (Table 2). There was no difference between treatments on incidence and severity of stem end rot. However, prochloraz had less than half the severity of stem end rot than the water dipped control (p = 0.076). The fatty acids treatment also showed a tendency to reduce stem end rot severity. There was no significant difference in incidence or severity of stem end rots and body rots between any of the fungicide treatments and the water dipped control.

Table 2. Effect of post-harvest fungicide treatments on the severity and incidence of stem end rot, body rots and the incidence of sound ripe fruit at a 5% disorder threshold.

	Stem end rot		Body rots		Sound ripe fruit
	Severity	**Incidence[1]**	**Severity**	**Incidence[1]**	**Incidence**
Carbendazim	4.10	38.5	12.9	87.5 ab[2]	45.5
Azoxystrobin	4.66	45.2	16.8	93.9 b	56.3
Folpet	3.56	39.0	11.6	78.5 a	48.0
Fatty acids	2.83	45.6	14.8	94.4 ab	52.7
Benomyl	3.51	48.0	16.7	91.5 ab	57.5
Prochloraz	1.40	39.5	12.2	89.0 ab	46.0
Water	3.22	50.0	14.6	87.5 ab	54.5

[1]Percentage of fruit. [2]Means followed by the same letter within a column are not significantly different according to a One-Way ANOVA using a Tukeys family error rate of 5%.

Table 3. Pesticide concentration of dip solutions before, during and after dipping and whole fruit residue levels ± standard error of the mean (n=3).

Fungicide	**Concentration of dip (mg/ml)**			**Residue on fruit**	**USA MRL**
	Before	**During**	**After**	**(mg/kg)**	**(mg/kg)**
Carbendazim	0.5	0.42	0.44	0.75 ± 0.015	None set
Azoxystrobin	0.12	0.11	0.14	0.66 ± 0.080	2.00
Folpet	0.78	0.74	0.69	2.47 ± 0.348	25.00
Fatty acids (potassium salts)	3.3	3.4	3.1	0.72 ± 0.035	GRAS
Benomyl[1]	0.22	0.23	-	0.50 ± 0.043	3.00[2]
Prochloraz	0.37	0.34	0.34	2.17 ± 0.088	None set

[1]Concentration of carbendazim, a breakdown product of benomyl. [2]Expires 1st Jan 2008.

The incidence of sound fruit was similar across all treatments.

All fungicides treatment left a residue on the fruit that did not exceed the MRL set for the USA (Table 3). The residues were below the 20% limit set in the materials and methods. At the fungicide concentrations and fruit volumes tested, dipping fruit for 2 minutes did not remove any appreciable amount of fungicide from the solution (Table 3).

DISCUSSION

All fungicide treatments were ineffective in controlling ripe rots. Therefore, none of the fungicides tested would have merit to mitigate ripe rots in late season 'Hass' avocado fruit exported to the USA. There are a number of possibilities as to why the fungicides were ineffective.

It is possible that the advanced stage of infection in the fruit used was too great to be overcome by application of postharvest fungicide. The high rot level in the fruit was likely to be due to the late maturity of the fruit, as indicated by the high dry matter content. An earlier harvest may result in less rots and greater efficacy of postharvest fungicide application.

The trend for prochloraz to reduce the severity of stem end rots confirmed previous findings (Le Roux *et al.,* 1985; Everett, 2002). Prochloraz is most effective in controlling ripe rots when applied within 24 hours of harvest (Everett, 2002). Fungicide application was completed more than 24 hours after harvest, potentially reducing the efficacy of prochloraz in this trial.

The whole fruit residue found on fruit treated with folpet was less than 10% of the USA MRL. It is possible that the concentration of folpet could be increased two fold without exceeding a residue level equal to 20% of the USA MRL. The increased concentration of folpet may then have given better control of ripe rots. The concentration of folpet was determined by calculating the residue likely to be present immediately after drying that was approximately equal to 20 % of the MRL set for the USA. The 20% value was selected to safeguard against the possibility of the USA MRL being exceeded. It is possible that a concentration likely to leave a residue of 50% of the MRL set for the USA, would be sufficient to achieve rot control without a significant increase in the risk of exceeding the USA MRL.

All treatments were applied by dipping fruit for 2 minutes. It is possible that dipping is not the ideal application method for the fungicides evaluated. Inline spray application is commonly used in New Zealand to apply prochloraz to fruit destined for the Australian market. Inline application may be a more suitable application method for the fungicides evaluated to ensure effective ripe rot control.

The mean dip concentration of azoxystrobin was about 0.12 mg/ml, a greater concentration than the EC_{50} of azoxystrobin required to inhibit mycelial growth of *Colletotricum gloeosporioidies, Colletotricum acutatum, Botryosphaeria parva, Botryosphaeria dothidea* (Everett,1999). The dip concentration of Benomyl and prochloraz were at least 1000 times greater than the EC_{50} of each fungicide to inhibit mycelial growth of the five common avocado postharvest fungal pathogen (Everett,1999). Therefore, the concentrations of azoxystrobin, Benomyl and prochloraz were high enough to inhibit fungal pathogens *in vitro*, but unable to control ripe rots in late season 'Hass' avocados.

CONCLUSIONS

None of the fungicide treatments investigated show significant promise in controlling ripe rots at the concentrations used to warrant further investigation at this time.

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