Fungicides for *Pseudocercospora* control on avocados: A review, a trial and observations

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Almost all the work on the control of *Pseudocercospora* on avocados has been done in South Africa, at Westfalia Estates. Although occurring in South America, the West Indies, Mexico, Spain, Australia, Florida and the Far East, there are few research results on control from these countries, and general recommendations are the use of copper compounds with occasional mentions of carbendazim or chlorothalonil. Because there are numerous trade names for the same chemical, the chemical names are used throughout. (See **Table 1** to convert to the known products.)

The history of control methods can thus be followed in the SAAGA yearbooks. Copper oxychloride (CuOCl) and benomyl have been the core chemicals, with excursions into triazoles, strobilurins and others. In order not to re-invent the wheel, a look at the findings will be illuminating.

The Darvas era

Joe Darvas initiated detailed work on *Pseudocercospora* for his PhD (Darvas, 1982). Throughout the 70s Westfalia had used benomyl exclusively but were concerned about resistance build-up. A wide range of chemicals was screened. Fosetyl-Al and captab were ineffective. The triazoles; etaconazole, propiconazole and bitertanol, and the dicarboxamide procymidone were tested; none were very good and some increased post-harvest diseases. Prochloraz gave acceptable control of *Pseudocercospora* and bitertanol was effective on stem-end rot (SER). Thiophanate-methyl was less effective than benomyl. The two best chemicals were CuOCl and captafol, and Westfalia shifted to programs alternating CuOCl with benomyl, as benomyl noticeably reduced post-harvest diseases; copper to a lesser extent and captafol appeared to increase these. Captafol also left a perceptible chemical smell on the fruit, was allergenic, and was soon withdrawn from the market.

Some effort was spent on stickers, with Nu-Film being held out as enhancing control, but effects were small.

Spray timings were worked out, "two spray benomyl treatments provided acceptable control and the timing with November and January applications was near to optimum" (Darvas, 1982). Nowadays, earlier periods are favoured, based on Darvas' spore release equation.

At some time, an unofficial agreement was reached in the subtropical industry that prochloraz would be retained for post-harvest control and not used in the field, so it was not tested further.

The Lonsdale era

These were the first efforts to reduce copper residues, more from a pack house point of view than from marketing considerations. Triazoles were tested on their own, and of these penconazole was very poor, cyproconazole poor, triadimenol and fluzilazole were reasonable, but not as good as copper (Lonsdale, 1991). These were also combined in programs with two copper sprays followed by a triazole, which did reduce residues. However, although statistically as effective as copper, the actual numbers were 10% lower, not a situation particularly acceptable to growers (ibid).

The following year trials showed that copper ammonium carbonate ($CuAmCO_3$, since replaced with copper ammonium acetate, (CuAmAc)) substituted for CuOCl reduced residues while being almost as effective as the latter. Triadimenol, fluzilazole and cyproconazole as the final spray of a copper program were less effective than an all copper or copper/benomyl program (Lonsdale, 1992).

Avogreen, a promising biological control agent, made its first appearance for *Pseudocercospora* control at this time (Korsten *et al.*, 1992), but after much effort has failed to make an impression and is currently little used.

The Duvenhage era

Tests on triadimenol as soil applied granules or injection started by Lonsdale, sometimes reasonably effective, continued for a while, but were eventually discarded (Duvenhage, 1994).

Cyproconazole, triflumizole and fluzilazole followed a similar route, showing some good effects and reducing residues but eventually falling by the wayside (Duvenhage and Köhne, 1995; 1996). $CuAmCO_3$ was confirmed as effective with lower residues. Wetters and stickers had no effect on disease but did reduce residues to an extent.

In trials where pulse fogging was used, $CuAmCO_3$ and benomyl gave good results at low disease pressure, with low residues. The standard high volume lance application of CuOCl was still best. The application method worked well, with low residues (Duvenhage and Köhne, 1999).

Strobilurins became available and were tested on their own, as was fluzilazole, again. The latter scored a perfect zero for control. The strobilurins were disappointing, azoxystrobin coming in at 40% control followed by trifloxystrobin and kresoxim-methyl. When combined in a program of a CuOCl spray followed by a strobilurin, however, they were more effective, azoxystrobin being acceptable and also giving good anthracnose control (Duvenhage, 2002).

The Willis era

Under high disease pressure CuOCl remained the best. The poor effect of azoxystrobin on its own was confirmed. Chlorothalonil was tested for the first time and was ineffective on its own, but left no residues and was acceptable on anthracnose. Azoxystrobin was excellent on anthracnose. Various additives to reduce the amount of CuOCl (Iron, quaternary ammonium compounds, chlorine dioxide) did not appreciably increase control (Willis and Duvenhage, 2003).

Reducing the amount of copper was approached by using a mistblower, low percentage copper compounds and oil as a sticker. Using a mistblower halves, or more, the amount of copper, with equivalent control to a full dose, lance applied program. The low percentage copper products had slightly reduced control.

Programs of four mistblower applications were compared. In this and all mistblower trials we have a problem, in that, in practice, a proper statistical trial would consume too many resources. Usually a row is treated and sufficient fruit assessed to be confident of the mean and S.D. Assuming the trees are equally susceptible and inoculum is evenly spread, this can be accepted. Alternating CuOCl and chlorothalonil or Agromos (yeast cell wall extract) gave the same good control as CuOCl or lance applied CuOCl, further reducing applied copper, but fruit residues were only slightly decreased. Cuprous oxide products had lower residues. One gave reasonable control, the other only supplied 2 kg/ha of actual copper and failed. Copper hydroxide products were inferior, one very poor (Willis, 2005). It must be noted that these were pruned trees, and penetration would be good.

The following year, for copper sprays, the application rate was increased to 8 200 L/ha except where lower rates were specifically tested. CuOCl was again among the best along with alternating azoxystrobin and CuOCl, if, and only if, the final spray was CuOCl (3-5% disease). Azoxystrobin on its own was useless. Other treatments had 10-20% disease. Interesting was that CuOCl used with Breakthru (a siloxane wetter) reduced anthracnose to low levels and SER to zero.

To summarise trial results to date:

- Nothing better than CuOCl has yet been found. Copper leaves unwanted residues on the fruit creating pack house problems. More importantly, our markets are insisting that less copper be used on fruit (plus there are concerns on copper build-up in soil).
- Carbendazim can be used on its own to good effect but is usually combined in a copper program where its kick-back effect helps, and it improves anthracnose control. It is slowly being phased out.
- Triazoles on their own have not been effective – Bitertanol, cyproconazole, etaconazole, fluzilazole, penconazole, propiconazole, triadimenol, triflumizole. When combined in a copper program they are better, but nothing outstanding. Some improve anthracnose control.
- Of the broad spectrum compounds, captab and chlorothalonil are ineffective on their own. Mancozeb and fentin hydroxide have never been tested. Prochloraz is reserved for post-harvest use. Chlorothalonil in a program with copper is as good as a CuOCl program and improves anthracnose control.
- Azoxystrobin, trifloxystrobin and kresoxim-methyl are poor on their own. Azoxystrobin in a CuOCl program works, if the last spray is CuOCl.
- Frequent sprays with lower annual copper application are equivalent to high volume, high copper programs.
- Oil is an effective sticker. Nu-film sticker and common wetters have little influence on control but can reduce residues a little.

Guessing at potentially useful fungicides

When selecting a fungicide it is useful to know the relationship of the target fungus to others, as a particular fungicide will tend to be effective on related fungi. As is usual, taxonomy based on morphological features is confusing, and major changes are being made with new access to sequence information. Deighton, in a series of papers in the 1970s, divided the *Cercospora* complex into three groups, renamed some of the species, and assigned the avocado pathogen to *Pseudocercospora* (Deighton, 1979). In some cases, *Cercospora* is associated with the teleomorph *Mycosphaerella*. Of the *Pseudocercosporas* the most widespread plant disease organism is *P. musae* (teleomorph *M. musicola*) causing Sigatoka of bananas. Based on the name, a fungicide effective against this should show promise for *P. purpurea* control.

In the one article containing a DNA analysis of the ITS region of *P. purpurea* it was found to be identical to *Cercospora apii* and it was proposed that it be reassigned the name *Cercospora purpurea* (Siboe *et al.*, 2000). Thus one should look at the fungicides used for control of *Cercospora* on sugar beets, soybeans and vegetables. This approach might be totally wrong, but we can't think of a better place to start. A side effect on anthracnose would also be a factor to consider.

On banana *Mycosphaerella*, the standard fungicide program is propiconazole alternated or mixed with mancozeb or chlorothalonil. The ~strobins, (azoxy-, trifloxy- and pyraclo-) are also widely used, as is the triazole epoxiconazole. Older products still in use are carbendazim and tridemorph and of course CuOCl. Resistance is known to several of the single action site fungicides and they are always combined with the broad spectrum fungicides.

Cercospora on sugarbeet is best controlled by a tetraconazole/~strobin/tin program. On vegetables, copper and chlorothalonil are standards with one of the ~strobins added in. Overall, of the ~strobins, pyraclostrobin appears to be the best. Difenoconazole and cyproconazole are also used. Notable is a trend toward mixtures like carbendazim/azoxystrobin and propiconazole/ azoxystrobin, a trend noticed in other situations as well – in fact many products are now marketed only as mixes.

Although there are scores of fungicides, many new developments of old chemistry, and a surprising number of new compounds, one cannot test or even access all. The points under consideration are effectivity, reduced visible residue, acceptance by the market, affordability and availability. Some will never make it to market for acceptance (toxicity) or marketing reasons, so we have concentrated on those that are being developed or are already widely used.

We then started asking around about the various possibilities.

Contact fungicides

Copper compounds are going to be with us for a long time. Two problems are attached, residues and pressure from the markets to reduce the amount applied. Formulations, hydroxide and oxide versus oxychloride, lower dose rates and so on are being investigated, but no huge differences have been identified. Price keeps increasing and the copper price went from $1700/ton in 2008 to $2700 this year.

Chlorothalonil has potential, but only as part of a program, as it is not effective when used on its own.

Fentin is very effective against Cercospora and Clado-

Table 1. Common names and a product name for fungicides (many are sold under a variety of names). Cost and dose rate for high volume lance application of fungicides potentially useful for Pseudocercospora control are given

Common name	Product	Pack	Rand	Dose/100L	R/100L	Av	An	My	Cr
		kg/L		g/ml					
azoxystrobin	Ortiva 250 SC	1	467	30	14.00	*	*	*	*
benomyl	Benlate					*	*	*	*
bitertanol	Folicur						*	*	*
boscalid/pyraclostrobin	Bellis	1	495	50	24.75	*	*	*	*
captab	Captan								
captafol	Difolatan								
carbendazim	Knowin 500 SC	25	4481	55	9.86	*	*	*	*
chlorothalonil	Bravo 720 SC	20	2149	200	21.49	*	*	*	*
copper ammonium carbonate/ acetate	Copper Count N					*	*	*	*
Copper hydroxide	Copstar	20	965	350	16.89	*	*	*	*
Copper oxychloride	Demildex 850 WP	25	1370	300	16.44	*	*	*	*
Cuprous oxide	Nordox 830 WP	10	1400	100	14.00	*			
cyproconazole	Alto								
difenoconazole	Score 25 EC	5	3338	50	33.38		*	*	*
epoxiconazole	Opus						*	*	*
etaconazole	Vangard								
fentin hydroxide	Supertin 480 SC	10	2500	50	12.50				*
fluzilazole	Capitan								
fosetyl-Al	Aliette								
kresoxim-methyl	Stroby								
mancozeb	Dithane 800 WP	25	1986	200	15.88		*	*	*
mineral oils	Various					*		*	
prochloraz									
procymidone	Sumisclex								
propiconazole	Tilt 50 EC	5	858	32	5.49		*	*	*
pyraclostrobin	Cabrio 250 EC	5	3250	20	13.00		*	*	*
tetraconazole	Eminent						*	*	*
thiophanate-methyl	Topsin								
tridemorph	Vanish 750 SC	1	269	50	13.44			*	
trifloxystrobin	Flint 50 WG	1	755	10	7.55		*	*	*
triflumizole	Terraguard								

Prices will be dated by the time this research is published.
Av = used and/or registered on avocados somewhere.
An = effective against anthracnose in tree crops.
My = used against *M. musicola* (banana Sigatoka, also other crops).
Cr = used against *Cercospora* of vegetables, carrots, sugar beet, etc.
Doses are given for high volume lance application. Especially for triazoles, if water is reduced (mist blower), dose per 100 L must be increased to give the same per tree rate.

sporium (both associated with the Mycosphaerella group). It is, however, a heavy metal, and unlikely to be acceptable.

Mancozeb might be useful, but is on the endangered list, as there is market resistance to its use, and it might not be permitted for more than a few years. Possible as an early spray.

Oils. Useful as a sticker. It has some fungicidal effect against Mycosphaerellas, related to the oil density.

Variable systemic

Boscalid. Boscalid is a newish broad spectrum systemic fungicide which is finding wide acceptance on many crops. It controls Cercospora and Mycosphaerella among others. It is usually sold mixed with epoxiconazole or pyraclostrobin or other chemicals to broaden activity and as a counter to resistance build-up. It is being registered as the pyraclostrobin mix (Bellis or Pristine) in Florida for anthracnose control on avocados. BASF have done some trials with Boscalid but find no particular advantage, or as they put it "value added". They will not be going for registration.

Carbendazim is also under threat regarding acceptance, but still good for early sprays.

Tridemorph is an old chemical but effective against Mycosphaerella and Cercospora.

Strobins. Of three strobins, azoxystrobin might be a future part of an avocado spray program if registration proceeds. When it comes to Cercospora control, pyraclostrobin appears to have the edge. BASF have tested pyraclostrobin on avocados with good results. However, getting harmonised MRLs for this will cost them R4m and the market is not big enough to justify this, so they are unlikely to pursue it.

Triazoles. A number of triazoles were previously tried with little success. This should not be, and perhaps using them as Willis has done with chlorothalonil in a copper program will be more successful. Propiconazole needs retesting and difenoconazole is a potential candidate. BASF have tested epoxiconazole in combinations and low doses and it is phytotoxic. Tetraconazole is not yet available in South Africa, as far as we can establish.

Others. Imizalil and prochloraz are 'reserved' for post-harvest. Prochloraz should be retested in a program as an early spray.

Which leaves us with: copper and carbendazim and as registered standards and the following to be checked out: azoxystrobin, chlorothalonil, fentin hydroxide, tridemorph, pyraclostrobin, trifloxystrobin, difenoconazole, propiconazole and prochloraz. Lab screening is not regarded as a proposition. The fungus grows extremely slowly, spores are produced with difficulty in culture and all that would be possible are yes/no answers to a dilution series. All of the chosen fungicides are expected to work to some extent. Potassium silicate was added by request, excellent on 'grasses', effective on few broadleaved plants.

Accordingly, a screening trial with only two replicates was set up.

MATERIALS AND METHODS

A 14-year-old 'Fuerte' orchard planted at a spacing of 3 m x 6 m (555 trees/ha) with a history of Pseudocercospora was selected in the Schagen area of the Mpumalanga Province. The trial was laid out as a randomized block design with 16 treatments and 2 reps (4 tree plots). The trial was conducted during the 2007/08 season. Sprays were high volume lance application of 15-20 L per tree (8325 L/ha). Treatments are listed in **Table 2.**

Three sprays were applied during the season, on 9 Oct, 9 Nov, 5 Dec. These were followed by a CuOCl spray (CuOCl) at 300 g/hl on 28 Jan. Adjuvants, apart from the Cu/Oil treatment, were not used.

Data from a preliminary (on tree) rating on the 5th

Table 2. Treatments

Active ingredient	Product	Product dose / hL
Unsprayed		
Copper oxychloride	Demildex 850 WP	100 g
Copper oxychloride	Demildex	200 g
Copper/Oil	Demildex / BP med oil	200 g + 250 ml
Copper oxychloride	Demildex	300 g
Mancozeb	Dithane M45 800 WP	200 g
Chlorothalonil	Bravo 720 SC	200 ml
Carbendazim	Bendazid 500 EC	55 ml
Difenoconazole	Score 250 EC	50 ml
Prochloraz	Omega 450 EC	150 g
Propiconazole	Tilt 250 EC	32 ml
Azoxystrobin	Ortiva 250	30 ml
Pyraclostrobin	Cabrio 250 EC	20 ml
Fentin Hydroxide	Supertin 4L 480 SC	50 ml
Tridemorph	Vanish 750 EC	50 ml
Potassium Silicate	20% SiO_2	2 000 ml

May was used to determine an acceptable sample size for evaluation of *Pseudocercospora*. Fruit were harvested on the 12th May. In each treatment, 30 fruit were harvested from the middle 2 trees of each 4 tree plot, from all sides of the canopy. Fruit were evaluated for Pseudocercospora incidence using a scale of 0-3, where 0 = no symptoms, 1 = 1-5 lesions, 2 = 6-10 lesions and 3 = more than 10 lesions. Fruit samples from each treatment (24 fruit per plot) were subsequently washed in a 0.5% calcium hypochlorite solution, rinsed in water, waxed with Avoshine and fan dried to mimic standard commercial pack house procedures, except prochloraz was excluded. The fruit were stored for 28 days at 5.5°C to allow for post-harvest disease development, ripened at room temperature and evaluated for anthracnose and stem-end rot when eat-ripe. A rating scale of 0-3 was used, 3 being severe. Rating data was expressed in terms of a disease index scale ranging from 0 to 100 according to McKinney (1923).

RESULTS AND DISCUSSION

Results are presented in table format without averages. As can be seen, the results for certain products varied widely between replicates. Either the product is not robust, certain trees had higher disease inoculum or were otherwise weakened, or spraying was not as good as we thought.

A mistake was made in this trial in that, we believed at the time, the early sprays were the most important. Not wanting to waste too much fruit, and for other reasons, the final spray was a blanket copper spray over the treatments in January. This now appears to be the most important spray (see 'Observations', below), thus the test chemicals are being favoured.

Tridemorph, fentin hydroxide and chlorothalonil all caused leaf toxicity of various degrees but fruit were unaffected.

Pseudocercospora. Disease pressure was high as shown by the untreated control. Best control was obtained with the Cu 300, Cu 200+Oil and Cu 200 treatments.

Of the multisite, broad spectrum chemicals, tridemorph and potassium silicate need be considered no further, fentin hydroxide was reasonable and consistent, where mancozeb and chlorothalonil, although averaging the same were inconsistent over replicates, varying by a factor of ten. Prochloraz was acceptable, carbendazim less so (the orchard has a history of benomyl usage). Of the triazoles, difenoconazole was better than propiconazole and close to CuOCl in control, but was used at a higher rate and is expensive. Of the ~strobins, azoxystrobin was superior to pyraclostrobin, an unexpected result.

Anthracnose. All fungicides, bar tridemorph, potassium silicate and perhaps carbendazim, had a positive effect on anthracnose, the latter being poor (see history, above). The others were more or less equivalent within the random noise of the trial.

SER. Disease was relatively low, propiconazole and chlorothalonil perhaps being slightly less effective than the others. For Anthracnose and SER combined, mancozeb and azoxystrobin stand out as having zero disease over all replicates.

There is, as yet, nothing to supplant CuOCl at 3 g/L. It would appear that 2 g/L of CuOCl is equivalent, especially with oil as a sticker. 1 g/L varied widely between replicates but is seen as being too low.

Of the other products tested, chlorothalonil and mancozeb might have a place in a program, but the variation between replicates is worrying. Prochloraz, azoxystrobin and difenoconazole were more consistent in their Pseudocercospora control. These three and perhaps mancozeb may have a place in a program with copper, especially in view of their side effects on

Table 3. Percentage disease by treatment, disease and replication

Treatment	% P~cercospora		% Anthracnose		% SER	
	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2
Control	97.8	100.0	18.8	19.4	5.8	18.1
Cu 100	4.4	20.0	0.0	0.0	4.5	1.5
Cu 200	1.1	1.1	0.0	4.5	2.9	3.0
Cu 200 + Oil	0.0	1.1	0.0	2.9	0.0	5.8
Cu 300	1.1	0.0	0.0	4.3	0.0	0.0
Mancozeb	2.2	25.6	0.0	0.0	0.0	0.0
Chlorothalonil	11.1	1.1	4.5	0.0	7.6	2.8
Fentin hydroxide	7.8	7.8	2.9	0.0	1.4	0.0
Tridemorph	17.8	42.2	12.1	0.0	3.0	3.0
Pot Sil	30.0	26.7	8.7	11.6	1.4	2.9
Prochloraz	4.4	1.1	0.0	3.0	0.0	3.0
Carbendazim	11.1	5.6	9.7	1.6	2.8	1.6
Difenoconazole	3.3	0.0	0.0	2.8	1.6	0.0
Propiconazole	7.8	13.3	1.5	12.1	1.5	15.2
Pyraclostrobin	5.6	11.1	4.5	0.0	1.5	0.0
Azoxystrobin	4.4	0.0	0.0	0.0	0.0	0.0

anthracnose and SER.

OBSERVATIONS

Considerable use is made of Darvas' prediction equation for deciding on when to commence spraying. However, this equation was derived from only 10 data days, Jan 27 to Feb 6 in 1979. Two of those days account for most of the prediction efficiency. Also, the equation is only really valid for temperatures between 20° and 26°C. On a weekly average data set covering six months, no useful regression equation could be derived. So, someone needs to get out there with paper bags, a spore trap, a weather station and bring the equation up to date.

Concomitantly, the critical periods for spray applications also need to be revisited. Darvas did bagging trials to determine infection periods but the raw data is not given and regression equations can hide a multitude of sins. The trend, however, was that fruits exposed in November had more disease than those exposed later in the season. In a spray timing trial, Nov/Dec and Jan/Feb sprays have the most effect, early October and Mar/Apr applications not being so important. Darvas considered the November and January sprays to be the optimum and later trials were done at these times (Darvas, 1982).

A staggered spray trial was done by Boshoff *et al.* (1996) in KwaZulu-Natal, in which trees were sprayed with CuOCl monthly from Sep to Mar, a second treatment from Oct to Mar and so on, until the last treatment which was only sprayed in March. Control was nil for the March only spray, poor for the March and February treatment, good for the January through March treatment and there was no further improvement by adding earlier sprays.

Willis' 2007 trial is illuminating. This was a mistblower trial, C = CuOCl, O = azoxystrobin and B = chlorothalonil. For the purposes of this exercise the influence of azoxystrobin and chlorothalonil can be disregarded (as evinced in other trials).

Oct	Nov	Dec	Jan	% Dis
O	O	O	O	57.5
C	C	O	O	31.5
O	C	C	O	10
O	O	C	C	3.2
C	B	C	B	9.6
O	C	O	C	4.8
C	C	C	C	4.3

Note that the three treatments with lowest disease all have a CuOCl application in January, the next best, an application in December. This trend holds for data from previous trials as well.

Currently, the perceived wisdom (at least ours) is that spraying in the October/November period as soon as "z"-values rise above 5 is most important. This appears to be erroneous in that the above shows that the December and more particularly January sprays are the critical ones. The Boshoff (1996) trial also implicated the late sprays as being important for anthracnose control. Azoxystrobin on its own is ineffective against *Pseudocercospora*, but alternated with or followed by a copper (as long as the latter application occurs in January) the program does work. Either early copper sprays are so much window dressing and can be eliminated, or they can be substituted with less effective chemicals to reduce total copper. There may also be some form of synergy or eradication of early infections going on. This is not particularly good news, as no product has yet been shown more effective than copper, and the above implies that the last spray must be copper.

We are faced with two problems as regards copper: Physical residues on the fruit at harvest and market pressure to reduce copper applied over the season.

Physical residues can be attacked in a number of ways. Cuprous oxide and copper hydroxide leave lower fruit residues but appear to be slightly less efficient than CuOCl. To reduce costs they tend to be used at lower doses, and this can backfire when actual copper applied falls below about 0.8 g/L (= 1.6 g/L CuOCl) in a spray (Willis, 2005). Pack house washing and brushing removes most of the visible residues. There are situations where this is not enough. When extracting copper from ores, one process is leaching with dilute sulphuric acid, acidic ammonium chloride or other mixes. A quick and dirty lab trial showed that a 30 second dip in dilute sulphuric acid removed all visible residues of copper, without affecting the fruit. Could a similar process not be integrated into pack house procedures for those batches requiring extra treatment? The use of oil as a sticker exacerbates the problem. Oil/copper residues can be removed with an oily cloth, or a detergent needs to be included in the dump tank. Alternately wetter/stickers need to be reinvestigated to find one as good as oil but which washes off easily, somewhat contradictory ideas.

Willis (2004, 2005, 2006, 2007) has gone a long way in demonstrating how to reduce **total copper applied per season**. This is the biggest challenge, forced on the industry by overseas markets.

Application methods play a large role. Mistblowers are great, if the trees are open, if the ground is flat. Foggers do not seem to have many adherents, and are subject to similar restrictions. Electrostatic applicators and microspinners have not been tested.

In more detail: In Willis (2004), lance applied CuOCl, 3 applications used 63 kg/ha/yr. Percentage control was not reported. Four applications with a mistblower at 3 500 or 5 000 L/ha, with or without light oil, reduced the copper to 21 and 30 kg/ha/yr respectively. CuAmAc four times at 10 000 L/ha reduced the copper further to 16 kg/ha/yr, and there was little visible residue. All gave similar control. Copper hydroxide at 8.4 kg/ha/yr copper was slightly inferior. Copper oxide at 3.6 kg/ha/yr failed dismally. It would appear there is a lower limit to the copper that must be applied.

In Willis (2005) two lance applications applied 45 kg/ha/yr of copper. Four mistblower applications reduced this to 30 kg/ha/yr. Alternating CuOCl and chlorothalonil (which is only partially effective) reduced the copper applied to 15 kg/ha/yr, as did reducing the CuOCl to 2 g/L with Agromos. These were all equally effective. Cuprous oxide at 15 kg/ha/yr copper was less (but not statistically) effective. Where products used 8.4 or 2.1 kg/ha/yr of copper they fell out of the bus.

Willis (2005) confirmed these trends. Two applications by lance at ~70 kg/ha/yr of copper was equivalent to four mistblower applications at ~25 kg/ha/yr copper or two applications of copper plus two of a less effective chemical. If one fell below ~15 kg/ha/yr, copper control was less effective, although statistically these were all equivalent. In 2007, Willis again added weight to the evidence. Four CuOCl applications, a total of ~50 kg/ha/yr was among the best, but equivalent were two applications at ~25 kg/ha/yr with two applications of a secondary chemical, as long as the last copper application was in January.

Sticking one's neck out, some general principles may be suggested:

- Copper oxychloride is the best available chemical for *Pseudocercospora* control.
- 15 kg/ha/yr is the absolute minimum actual copper. This may be too low as it equates to 75 g/100 L high volume application and 100 g/100 L gives poor control.
- Critical sprays are November and January or December and January.
- Several products can assist and reduce anthracnose and SER.

Where to?

As mentioned above, the epidemiology of the disease needs updating: **What triggers spore release?** We suspect this is heavily tied to rainfall with a lesser temperature component. The usual October rain episodes start the epidemic off, but it does not get into full stride until mid November and peaks in January.

At what growth stage is the avocado susceptible?

Conventional wisdom has it that the avocado has to be larger than 40 mm long before becoming susceptible, and that symptoms appear three months after inoculation. Probably true, as we suspect this was based on work of Darvas. However, we cannot find the actual data. One 1922 report refers to this resistance, but the author is discussing anthracnose. This affects spray timing, and a complicating factor is that avocados on the North-West aspect may have exceeded this size, while those on the SE are still flowering.

Further, although azoxystrobin and triazoles are relatively ineffective on their own, when combined with copper sprays, a program is very effective at reduced total copper applications. Schutte (pers. comm.) working on Guignardia on citrus has shown there to be unexpected synergies between quaternary ammonium compounds, siloxane wetters, strobilurins and contact fungicides. These are areas where future research should be concentrated.

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