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Avocado fruit diseases and their control in South Africa

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SYNOPSIS
The most important pre-harvest fruit disease of avocado at Westfalia Estate was Cercospora spot, caused by Pseudocercospora purpurea*. A statistical model, suitable for forecasting the number of conidia released into the orchard's atmosphere, was developed. The model was used to determine critical infection periods, thus facilitating accurate timing of fungicidal sprays. Infections by the fungus taking place early in the growing season resulted in the highest disease incidence. A three-month latent period occurred in the disease cycle. Cercospora spot can be controlled by timely application of benomyl, captafol, Cu-oxychloride and Cu-hydroxide.*

The following post-harvest diseases were recognised at Westfalia Estate. stem-end rot, caused by Thyronectria pseudotrichia*,* Colletotrichum gloeosporioides*,* Dothiorella aromatica*,* Phomopsis perseae *and to a lesser extent,* Fusarium decemcellulare*,* Pestalotiopsis versicolor*,* Botryodiplodia theobromae*,* Rhizopus stolonifer, Fusarium sambucinum, Fusarium solani *and* Drechslera setariae*, anthracnose, caused by* C. gloeosporioides*; Dothiorella/Colletotrichum complex fruit rot, caused by* D. aromatica *and* C. gloeosporioides*. Infections taking place later in the growing season resulted in a higher post-harvest disease incidence. The natural latent infections of* C. gloeosporioides *and* D. aromatica *built up in the fruit during the rainy growing season, gradually decreased during the dry harvest season. Pre-harvest sprays with benomyl, captafol, Cu-oxychloride and Cu-hydroxide gave some control against post-harvest diseases. The length of the ripening time had an influence on the incidence of post-harvest diseases and any treatment which extended shelf-life also increased disease incidence. This increase could not be fully counteracted by application of fungicides to the fruit. Moisture of any source on the fruit at harvest greatly aggravated post-harvest diseases, whereas sealing of the cut-end of the fruit pedicel with wax plus fungicides, as well as removal of the pedicel, reduced losses due to stem-end rot. Reasonable control of post-harvest diseases was achieved by post-harvest application of the fungicide, Prochloraz.*

INTRODUCTION

A five-year investigation was conducted at Westfalia Estate to determine the major pre- and post-harvest fruit diseases of avocados (*Persea americana* Mill) and to devise effective control measures. Westfalia Estate is the largest single avocado grower in South Africa, with about 600 hectares planted mainly with the cultivars Fuerte, Hass, Edranol and Ryan. The estate is situated in the North-Eastern Transvaal and the average annual rainfall is 1 300 mm, most of which falls in summer. The warm and humid climate of the estate creates conditions conducive to a wide variety of disease problems on avocados.

The pre-harvest fruit disease, Cercospora spot, was first described in South Africa by Brodrick, Pretorius & Frean (1974), but was incorrectly identified as Phomopsis spot. It spread rapidly and it is now found in all avocado centres of the Lowveld and occurs in Natal as well.

In South Africa, stem-end rot was reported by Jacobs (1974), who believed that it was mainly a problem on irradiated fruit and by Gorter (1977), who stated that it was caused by *Botryodiplodia theobromae* Pat. Doidge (1924) described *Colletotrichum gloeosporioides* (Penz) Sacc for the first time in this country as the cause of anthracnose. Gorter (1977) reported *Botryosphaeria ribis* from avocado fruit spot.

RESULTS AND DISCUSSION

Pre-harvest fruit diseases

Cercospora spot disease was the most important pre-harvest avocado fruit disease at Westfalia Estate. Losses were appreciable even in commercially treated fruit (up to 12 per cent); losses up to 69 per cent were recorded for unsprayed fruit. Fuerte and Ryan cultivars were considerably more susceptible to the disease than Edranol and Hass. The pathogen causing Cercospora spot disease is *Pseudocercospora purpurea* (Cke) Deighton (syn *Cercospora purpurea* Cke). Inoculated Fuerte produced typical symptoms, which agree with descriptions given by earlier workers (Stevens, 1922; Zentmyer, 1953; Brodrick *et al*, 1974). Two distinct disease stages were recorded. At first, the green epidermis of the fruit became slightly darker at the site of infection and a swelling of the underlying tissues caused the spot to rise above the level of the epidermis. As the epidermis cells were killed and the tissues dried out, the spot became sunken and darker with horizontal cracks. Leaf symptoms were common on mature Fuerte leaves. Most of the fresh *P. purpurea* isolates produced conidia on artificial media when kept continuously under near-ultra-violet light. Sporulation began ca 10 days after inoculation and a fair amount of conidia was produced for about another 10 days, after which the fungus became sterile. These cultures regained the ability to sporulate if transferred to sterile, freshly-cut avocado pieces, but again only for a limited period. The incidence of *P. purpurea* did not differ significantly in the two types of lesions (Table 1). The occurrence of *C. gloeosporioides* was considerably higher in sunken lesions and these spots also contained more secondary fungi.

TABLE 1 Percentage incidence of *P. purpurea* and associated organisms in raised and sunken Cercospora spots of Fuerte

Organisms	Percentage occurrence N=100 fruit	
	Raised (young) spots	Sunken (old) spots
Pseudocercospora purpurea	41,0	50,5
Colletotrichum gloeosporioides	2,5	24,5
Phoma spp	0	1,5
Cladosporium spp	2,0	2,5
Pestalotiopsis spp	1,5	2,0
Unidentified fungi	0	1,5
Sterile isolations	53,0	17,5

A highly significant correlation (R^2 = 0,8754) was found between the spores trapped daily in the orchard and rainfall, and temperature figures. The model to forecast the number of conidia in the atmosphere of an established Fuerte orchard at Westfalia Estate was: Z (number of conidia) = 24,8 (constant) -- 0,93 X (X is temperature in °C) + 0,25 Y (Y is rainfall in mm). In practice, the number of conidia first reached significant proportions with the onset of the warm, rainy summer period and often great numbers of conidia were detected even as late as March, when harvesting of Fuerte had already started. A significant correlation was found between the number of Cercospora spots on the fruit exposed to natural infections and the exposure periods. Fuerte fruit exposed early in summer, were more severely infected than fruit exposed later in the growing season (Figure 1).

Good Cercospora spot control was achieved by the foliar sprays of benomyl, captafol, Cu-oxychloride and Cu-hydroxide (Table 2). The same fungicides (except Cu-hydroxide) were tested and found effective against Cercospora spot in the Nelspruit area by Kotze, Du Toit &Durand (1982).

TABLE 2 Control of Cercospora spot on Fuerte by pre-harvest foliar sprays with fungicides applied in November and January.

Treatments	Mean number of Cercospora spots per fruit N=10 400 fruit
Benomyl 0.025% ai + Nu Film 0.02%	2.6 be
Cu-oxychloride 0.25% ai + Nu Film	3.1 be
Cu-hydroxide 0.15% ai + Nu Film	3.9 b
Captafol 0.16% ai + Nu Film	0.6 c
Control	9.6 a
Means followed by the same letter do not differ significantly at P=0.05 level (Duncan's New Multiple Range Test).	

TABLE 3 The incidence of post-harvest diseases on Fuerte sprayed twice with fungicides before harvest

Treatments	Time of application	Mean disease severity 0 to 10 index N = 4 000 fruit		
		Stem-end rot	Anthrac-nose	Doth/Coil fruit rot
Benomyl 0.025% ai + Nu Film Benomyl 0,025% ai + Nu Film	Nov Jan	0,50 a	0,42 a	2,21 a
Captafol 0.08% ai + Nu Film Captafol 0,08% ai + Nu Film	Nov Jan	0,14 b	0.21 ab	1,39 be
Captafol 0,08% ai + Nu Film Cu-oxychl 0,25% ai + Nu Film	Nov Jan	0,14 b	0,16 b	1.01 cd
Captafol 0,08% ai + Nu Film Benomyl 0,025% ai + Nu Film	Nov Jan	002 b	0,10 b	0.69 d
Control		0.21 a	0,17 b	1,91 ab
Means followed by the same letter do not differ significantly at P = 0,05 level (Duncan's New Multiple Range Test).				

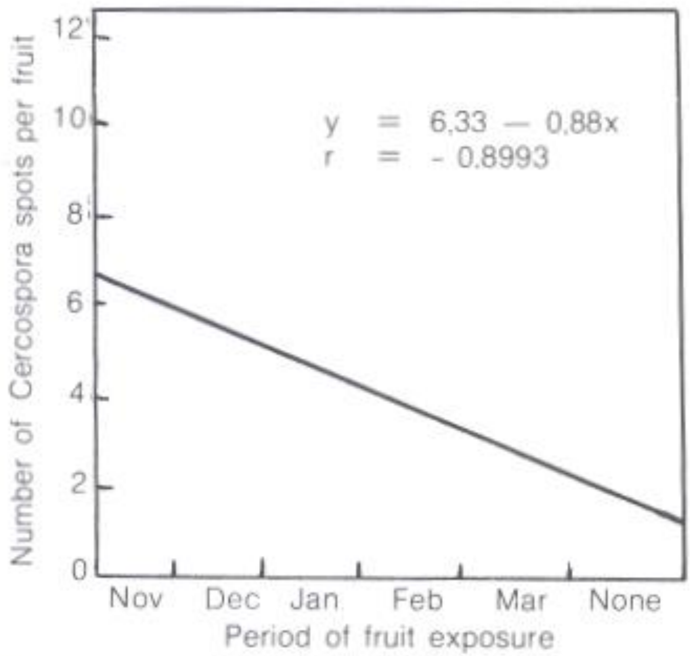

Fig 1 The incidence of Cercospora spot on Fuerte fruit exposed at monthly intervals to natural infections.

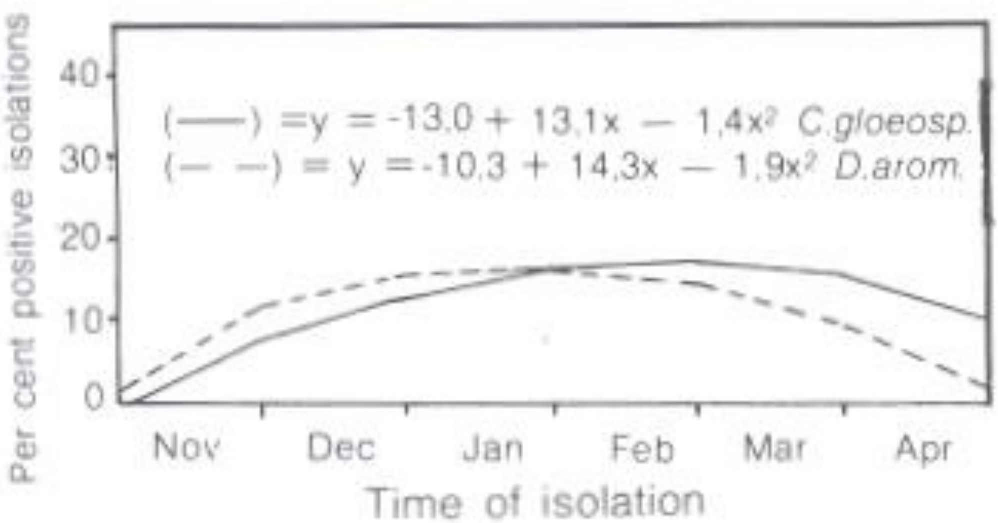

Fig 2 The incidence of latent infections of *C. gloeosporioides* and *C. aromatica* in naturally infected Fuerte fruit skin.

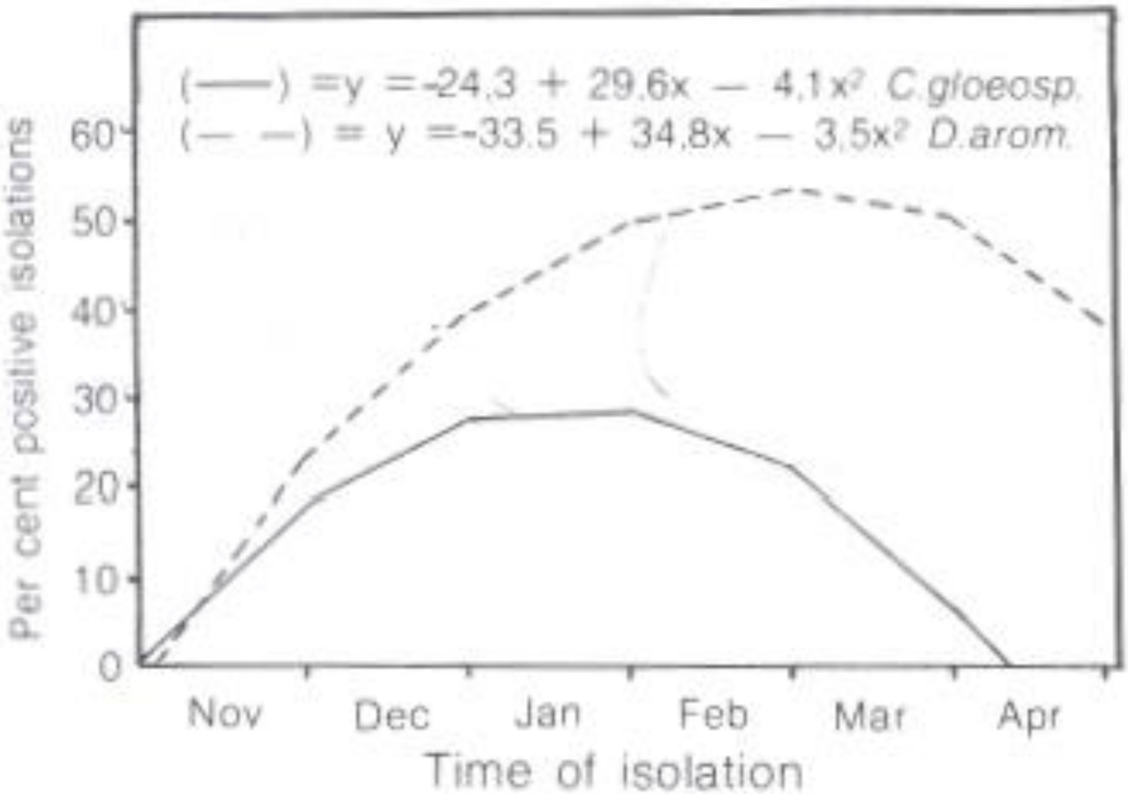

Fig 3 The incidence of latent infections of *C. gloeosporioides* and *C. aromatica* in naturally infected Fuerte fruit pedicels.

Post-harvest diseases

The most common fungus associated with stem-end rot in Fuerte fruit ripened either directly after harvest or after cold storage, was *Thyronectria pseudotrichia* (Schw) Seeler. The incidence of the second most common stem-end rot pathogen, *C. gloeosporioides*, increased after cold storage. A similar increased incidence was observed for *Phomopsis perseae* Zerova following cold storage. *Dothiorella aromatica* (Sacc) Petr & Syd was isolated relatively infrequently from both cold-stored and directly-ripened fruit. *Fusarium decemcellulare* Brick, *Fusarium sambucinum* Fuckel, *Fusarium solani* (Mart) Sacc, *Pestalotiopsis versicolor* (Speg) Steyart, *B. theobromae* and *Drechslera setariae* (Sawada) Subram. & Jain occurred only sporadically in stem-end rot. The temperature during ripening of avocado fruit also had an important effect on the development of post-harvest diseases, as indicated by experiments done by Fitzell & Muirhead (1983).

Pathogenicity of the fungi isolated from stem-end rot was investigated by pre-harvest inoculation of fruit on the trees. *C. gloeosporioides* and *D. aromatica* infected uninjured Fuerte fruit and caused both fruit rot and stem-end rot. *B. theobromae* caused stem-end rot only and *F. decemcellulare* induced small decay spots on softening fruit. None of the other organisms caused post-harvest diseases after pre-harvest inoculation. However, they were pathogenic in post-harvest inoculation through wounds.

No new information regarding the symptoms of stem-end rot and typical anthracnose as described by Horne (1931), Stevens (1922), Ocfemia & Agati (1925), Horne (1934) and Zentmyer (1953), evolved from this investigation. However, the superficial anthracnose caused by *C. gloeosporioides* had to be classified with Dothiorella fruit rot caused by D. aromatica as Dothiorella/Colletotrichum complex fruit rot (DCC). The difficulty of separating Dothiorella fruit rot from the superficial anthracnose on the basis of symptoms only, has previously been reported by Muirhead (1977).

The occurrence of latent skin infections by *C. gloeosporioides* and *D. aromatica* best fitted a non-linear regression model (Figure 2). The maximum build-up was recorded during the very rainy months of January and February, with a gradual decrease thereafter.

In the pedicel, the infections of *D. aromatica* reached maximum at a later stage and persisted in high numbers well into the harvesting season (Figure 3).

Acceptable control of post-harvest diseases was obtained with some preharvest fungicide sprays, in particular in spray programmes where benomyl and captafol were used in combination with Cu-oxychloride (Table 3). The increased losses encountered with benomyl treatment might have been due to increased tolerance of the postharvest pathogens to this compound. A similar tolerance developed in *P. purpurea* after prolonged use of benomyl at Westfalia Estate. Reasonable anthracnose control by pre-harvest sprays was also reported from Florida (Ruehle, 1943), Australia (Peterson & Inch, 1980) and from the Nelspruit area (Kotze, Kuschke & Durand, 1981).

Stem-end rot and DCC were statistically more severe on fruit harvested wet than on dry fruit. It was found that the rapid drying of wet fruit in the packhouse was not likely to reduce the problem satisfactorily, since moisture was retained in the lenticels of the quick-dried fruit and many latent infections were located in these tissues (Horne& Palmer, 1935).

The sealing of the cut-end of the fruit pedicel with wax plus fungicides was an effective means of controlling stemend rot. The usual waxing of export fruit slowed down the ripening process, but there was an increase in the severity of post-harvest diseases on these fruit. These increased pathological losses could only be partially reduced by the addition of fungicides to the wax. A recently tested fungicide, Prochloraz, may be used in the packhouse for a more effective control (Muirhead, Fitzell, Davis & Peterson, 1982; Rowell, 1983; Darvas, 1984; Darvas, 1985).

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