BLACK SPOT

Phyllosticta citricarpa (McAlpine) van der Aa

1 PATHOLOGICAL PROFILE

1.1 Distribution and status

Black spot of citrus, caused by the fungus *Phyllosticta citricarpa*, is important only as a fruit disease. All commercial cultivars are susceptible, but maturing lemons, Valencias and navel oranges, tangerines and grapefruit can be severely affected.

The disease is severe mostly in the hot, humid, low-lying subtropical regions, and occurs sporadically in lower summer rainfall areas, such as the Eastern Cape. The disease and pathogen do not occur in the Western and Northern Cape.

Pre-harvest symptoms usually appear during the later stages of fruit development and severely affected fruit drop prematurely. Post-harvest lesions may also develop prior to and during shipment. In terms of previous export regulations, fruit with approximately five or more lesions were considered unacceptable for export, but can be used for processing. However, the European Union has imposed stricter requirements in respect of black spot and now requires total freedom from symptoms. Heavily infected fruit is sometimes rejected by processors.

1.2 Description

Infections are caused by pycnidiospores and ascospores. The ascospores provide the primary source of inoculum on fruit. Their individual characteristics are as follows:

Pycnidiospores: These spores develop in pycnidia (Figure 1) which are formed on dead leaves on the orchard floor, on fruit and occasionally on fruit stalks. Pycnidia (115 to 190 µm in diameter) are brown or black in colour. Pycnidiospores are obovate to elliptical (8 to 10,5 µm x 5,5 to 7 µm), hyaline, aseptate, and multiguttulate, with a colourless, subulate appendix.

No special mechanism of pycnidiospore release from pycnidia exists and these spores are washed from pycnidia onto lower-hanging susceptible fruit by rain.

Ascospores: These spores develop in ascocarps (Figure 2), which are also formed on dead leaves on the orchard floor. They are aseptate, hyaline, multiguttulate, and cylindrical but swollen in the middle (12,5 to 16 µm x 4,5 to 6,5 µm), with obtuse ends, each having a colourless appendage. Asci are clavate, cylindrical and contain eight ascospores each. Ascocarps are mostly aggregated and globose (100 to 175 µm in diameter) with a non-papillate, circular ostiole.

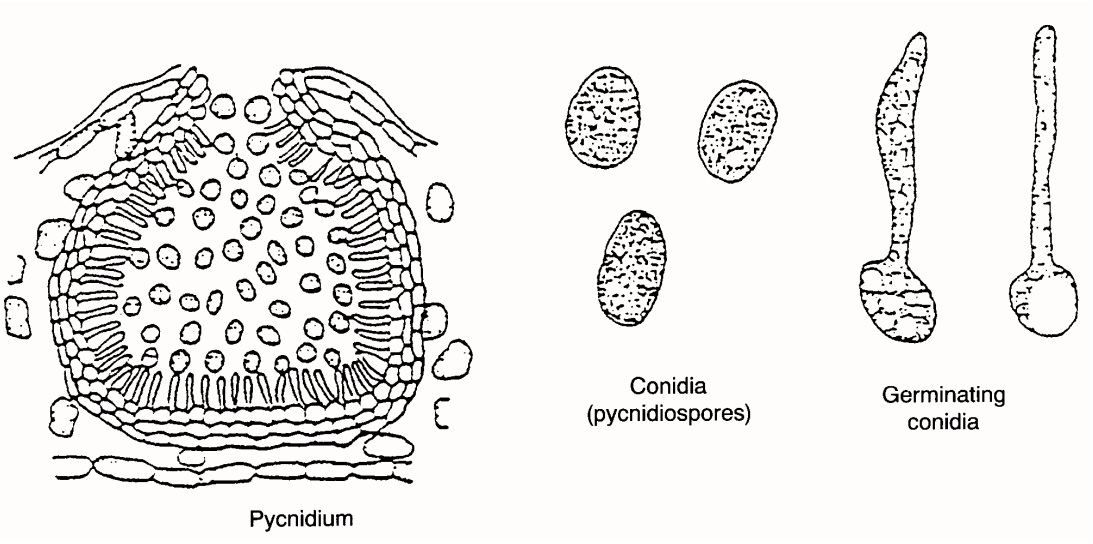

Figure 1. Pycnidium with pycnidiospores and germinating conidia of *Phyllosticta citricarpa* as commonly found on citrus fruit (Courtesy Reddick)

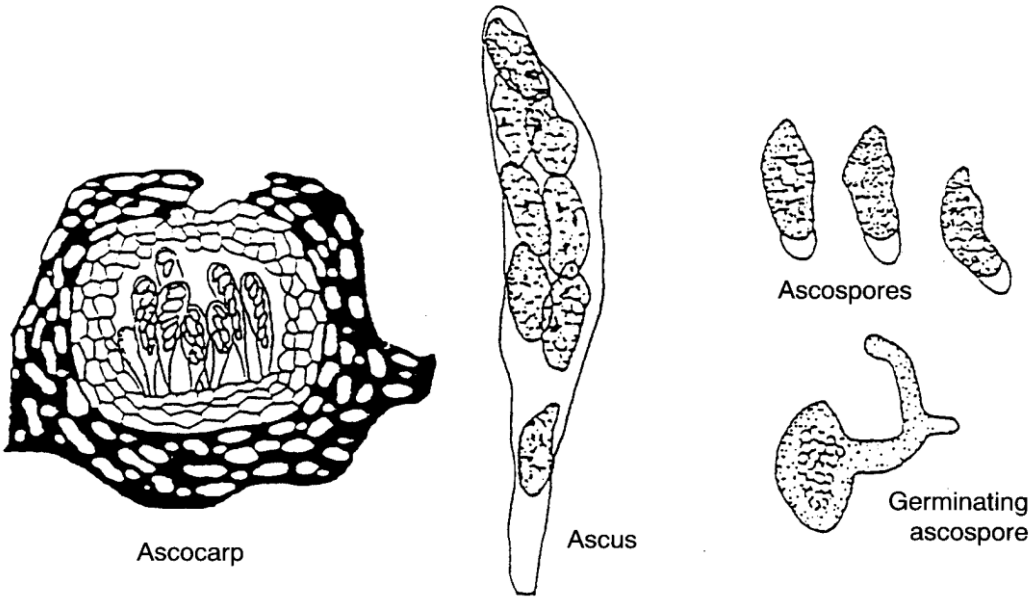

Figure 2. Ascocarp containing asci and ascospores of *Phyllosticta citricarpa* as found on fallen leaves which provide the main source of inoculum to citrus fruit (Courtesy Reddick)

The release of ascospores, which are the main source of inoculum, is triggered by frequently occurring rainfall with temperatures in the range of 17 to 33°C. The optimal temperature range for this fungus is 25 to 27°C.

Ascospores germinate and produce a germ tube and an appressorium under conditions when fruit remains wet for approximately eight or more hours. The appressorium is the swollen tip of the germ tube from which an infection peg develops which penetrates the cuticle. The infection peg expands into a tiny knot of mycelium between the cuticle and epidermis.

The fungus remains latent until the fruit become fully grown or mature, when it may grow further into the rind tissue to produce black spot symptoms.

1.3 Symptoms

1.3.1 Leaves

Infected leaves seldom show symptoms of the disease, but when present, appear as small necrotic spots with a greyish centre surrounded by a dark brown ring and a yellow halo. These symptoms are more common on lemons than on other cultivars.

1.3.2 Fruit

The first symptoms normally appear more than six months after fruit set. Symptom development on mature fruit is hastened by rising temperatures, high light intensity, drought stress and poor tree vigour.

There are four types of symptom expression on fruit:

Speckled-blotch (also known as false melanose):

Small lesions (1 mm) characteristically surrounded by tiny, dark speckles which develop into hard-spot lesions as the season progresses.

Hard-spot: This is the most typical black spot symptom and appears before the fruit colour changes from green to yellow. Pycnidia may be present in the centre of the lesion. These lesions occur mostly on the side of the fruit that is exposed to sunlight. When these lesions continue to enlarge and coalesce, the condition is termed virulent-spot.

Virulent-spot: These lesions develop late in the season when fruit is fully mature and temperatures rise during spring. Lesions are irregular and confluent and contain numerous pycnidia.

Freckle-spot: These lesions are slightly depressed and red in colour. They enlarge and give rise to craters of up to 3 mm in diameter. These appear after the fruit has coloured and individual spots may sometimes coalesce to form big lesions or even a tearstain effect similar to that caused by melanose.

1.4 Transmission

Ascospores, which are produced on dead leaves on the orchard floor, are forcibly discharged during rain and occasionally during irrigation, and disseminated by wind.

Pycnidiospores are extruded in a gelatinous mass from pycnidia, and because of their stickiness, rely on water for dissemination. Pycnidiospores can be a source of inoculum on out-of-season fruit or late-hanging fruit on which pycnidia may develop. Spores can then be washed onto the young fruit. Late hanging Valencias and lemons, which set more than one crop per annum, tend to have more of this type of infection than cultivars that are harvested earlier in the season.

1.5 Seasonal occurrence

Although the inoculum is present during rainy periods from October to April and ascospore discharges are at a peak during November to March, the critical CBS infection period occurs from October to January. It is therefore, important that young fruit is protected using fungicides from mid- (or late-) October and the protection must be uninterrupted until the end of the fruit susceptibility period. If the protection is interrupted, it must be demonstrated that no infection periods occurred during periods between the end of the recommended protection period of the previous spray and the application (or extent of curative action) of the follow-up spray.

The use of volumetric spore traps in conjunction with the monitoring of rainfall and temperature records, have been successfully applied in South Africa to determine the time of ascospore release. Infection forecasting services also assist in determining periods of CBS infection. Growers are advised to use CRI-PhytRisk (www.cri-phytrisk.co.za), which is an early warning system indicating when conditions are favorable for CBS infection and a tool for use, particularly, to decide when to use a product with curative action.

2 MANAGEMENT ASPECTS

2.1 Disease assessment

There are several factors that influence the susceptibility of citrus trees to the disease.

2.1.1 Tree age and vigour

Trees are susceptible from year one. Susceptibility increases with tree age. The disease is more severe on neglected or declining trees than on healthy trees. Trees that are sparsely foliated develop more symptoms as fruit are more exposed to high light intensity which stimulates symptom expression.

2.1.2 Citrus types

Lemons are extremely susceptible to black spot. In areas where black spot does not occur, any initial infection by the pathogen will occur on lemons. Thereafter, it can spread quickly to other types. In areas where the disease is endemic, lemon orchards should preferably be situated downwind and some distance away from other cultivars. In areas where there are no existing lemon orchards, and black spot is very sporadic, the planting of lemons should, from an epidemiological point of view, not be recommended.

2.1.3 Hail damage

Orchards that are damaged by hail are more susceptible to black spot and therefore should be harvested as soon as possible if export percentage permits.

If hail damage occurs early in the season, before or during the spraying period, the spray programme should be reviewed in terms of the timing of treatments, number of applications

and concentrations of products used. Growers requiring assistance in this regard should contact a consultant.

2.2 Control options

2.2.1 Cultural

Although commercial control of black spot can only be achieved through the use of plant protection products, the efficacy thereof can be enhanced by mulching of the orchard floor with a suitable material such as grass cuttings. Mulching accelerates the decomposition of the leaves bearing the ascocarps, causing a reduction in inoculum. The timing of mulching is extremely important and it should be applied after leaf drop during the period August to September to ensure complete coverage of the fallen leaves.

Since trees that are in poor condition are more prone to black spot than healthy trees, it is important to maintain tree vigour, especially in areas where disease pressure is high.

2.2.2 Plant protection products

Commercially acceptable levels of control of black spot can only be achieved through the use of plant protection products.

Preventive control of black spot with contact fungicides

When contact fungicides are used, spray applications have to be more carefully timed. The latent infection phase of black spot, which occurs between the cuticle and the epidermis of the rind, is out of reach of contact fungicides due to their inability to penetrate the rind. Spray programmes comprising these fungicides must therefore be aimed at prevention of fungal infection. Recommended intervals between sprays must not be exceeded. The maximum period that the different fungicides can protect fruit at registered dosages, is as follows:

Mancozeb	- 25 days
Copper oxychloride/ Copper hydroxide/ Cuprous oxide	- 35 days
Maneb	- 28 days
Dipotassium phosphate	- 28 days

Citrus fruit is susceptible to infection from fruit set until natural resistance against the disease develops in the rind by the end of January. Since initial infection seldom occurs before mid-October, the protection period should stretch from mid-October until the end of January. The registered preventive control options are listed in Table 1.

Corrective control of black spot with systemic fungicides

Systemic fungicides are capable of penetrating the epidermis and the cuticle, and killing the mycelium present. Existing lesions can also heal once the infection is eliminated. Benzimidazoles and strobilurins are all the systemic fungicides registered for CBS control. The addition of oil to the benzimidazoles and strobilurins is essential to ensure efficacy (Table 2).

Table 1. Preventive black spot control programmes (based on registered label recommendations)

Weather conditions	Fungicide	Dosage/100 ℓ water	Application date/Interval
		IMPORTANT: Labels **MUST** be consulted and strictly adhered to, for all products.	
Wet season	Mancozeb (WP)	200 g	First application after 100% petal fall in early October. Follow up with a further 4 applications at 25 day intervals.
		First two sprays: 200 g without oil **Last two to three sprays:** 150 g **PLUS** 600 ml light or medium mineral oil	Above normal rainfall in July to September: Apply 5 applications. Commence with the first spray after 100% petal drop. Apply the 4 follow-up sprays at 25-day intervals.
	Pennfluid (SC)	200 ml Or **Tank mix** 150 ml + 100 ml Citrole 100 + strobilurin	If normal rainfall occurs during July-September, apply during the 3rd week October and repeat at 25-day intervals for a further 3 applications. Do not apply later than February. Only use Citrole 100 in spray programmes with Pennfluid. Consult the strobilurin's label for its recommended rate with mancozeb. Do not use on mandarin cultivars.
	Copper oxychloride	200 g	4 applications at 30-35 day intervals commencing early October
	copper hydroxide	350 ml	4-5 high volume spray applications at 30-35 day intervals commencing mid-October to end January.
	Cuprous oxide	90 g or 90 g + 30 ml Azoxystrobin	Commence applications at 100% petal drop. Apply 4 applications at 30 to 35 day intervals thereafter. Apply 2 high volume full cover sprays. **1st application:** November **2nd application:** January

Weather conditions	Fungicide	Dosage/100 ℓ water	Application date/Interval
	Sporekill	**Tankmix** 100 ml + 100 g mancozeb **OR** 100 ml + 100 g copper oxychloride **OR** 100 ml + 100 g copper hydroxide	Apply preventatively, four full cover sprays at 25-30 day intervals. Apply first application before 15 October. Ensure thorough coverage of both foliage and fruit surfaces. Do not use pH-buffers in tank mixtures containing copper fungicides.
	Dipotassium phosphate	100 ml	Apply as two alternate full cover sprays, in a four spray programme with either copper or mancozeb, at intervals of 28 days commencing mid-October until the end January.
Normal Season	Mancozeb (WP/WG)	200 g **OR** First two sprays: 200 g without oil Last two to three sprays: 150 g	4 applications at 25 day intervals commencing the 3rd week in October.
	Pennfluid (SC)	**PLUS** 600 ml light or medium mineral oil 200 ml Or **Tank mix** 150 ml + 100 ml Citrole 100 + strobilurin	If normal rainfall occurs during July-September, apply during the 3rd week October and repeat at 25-day intervals for a further 3 applications. Do not apply later than February. Only use Citrole 100 in spray programmes with Pennfluid. Consult the strobilurin's label for its recommended rate with mancozeb. Do not use on mandarin cultivars.
	Copper oxychloride *	200 g	3 applications at 30-35 day intervals commencing the 3rd week in October.

Weather conditions	Fungicide	Dosage/100 ℓ water	Application date/Interval
	copper hydroxide	350 ml	4 high volume spray applications at 30 - 35 day intervals commencing mid-October to end January.
	Cuprous oxide	90 g	Apply the first application before the end of October. Apply 3 high volume sprays at 30 to 35 day intervals thereafter.
	Sporekill	**Tankmix** 100 ml + 100 g mancozeb **OR** 100 ml + 100 g copper oxychloride **OR** 100 ml + 100 g copper hydroxide	Apply preventatively, four full cover sprays at 25-30 day intervals. Apply first application before 15 October. Ensure thorough coverage of both foliage and fruit surfaces. Do not use pH-buffers in tank mixtures containing copper fungicides.
	Dipotassium phosphate	100 ml	Apply as two alternate full cover sprays, in a four spray programme with either copper or mancozeb, at intervals of 28 days commencing mid-October until the end January.
	Maneb	200 ml	Apply 4 to 5 sprays at intervals of 25 to 28 days. Apply the first spray at 100% petal drop. Intervals must be adjusted according to rainfall using shorter intervals when frequent rain has occurred since last spray. **WARNING:** When applying medium narrow range mineral oil in combination with maneb, do not exceed an oil concentration of 500 ml.

Weather conditions	Fungicide	Dosage/100 ℓ water	Application date/Interval
Normal and wet seasons	Mancozeb	200 g	Commence the treatment programme by applying as soon as possible after 100% petal drop.
	Azoxystrobin + Mancozeb/ Copper oxychloride + mineral oil	2× (20 ml + 150 g + 300 ml)	Follow-up after 21 days with the 1st application of azoxystrobin (approximately mid to end October) and repeat with a 2nd application of azoxystrobin six weeks later (approximately end of November to beginning of December).
	Mancozeb	200 g	If conditions remain favourable for infection, a further one to two applications of mancozeb should be made at 21 - 24 day intervals to provide protection during January and February.
	Mancozeb	200 g	Apply soon after petal fall.
	Flint + Mancozeb + mineral oil	2× (10 ml + 150 g + 300 ml)	Apply the first Flint spray 21-24 days after the **first** mancozeb application and the **second** Flint spray 6 weeks later.
	Mancozeb	200 g	Apply mancozeb 6 weeks after the second Flint application. Repeat the mancozeb application after 21-24 days if conditions favour the development of late infections.
	Mancozeb	200 g	Apply soon after petal fall.
	Pyraclostrobin + Mancozeb/Copper oxychloride + mineral oil	2× (10 ml + 150 g + 300 ml)	Apply the first pyraclostrobin spray 21-24 days after the **first** mancozeb application and the **second** pyraclostrobin spray 6 weeks later.
	Mancozeb	200 g	Apply mancozeb 6 weeks after the second pyraclostrobin application. Repeat the mancozeb application after 21-24 days if conditions favour the development of late infections.

Table 2. Corrective black spot control programmes (based on registered label recommendations)

Tree condition/age	Fungicide	Dosage/100 ℓ water	Application date/interval
	IMPORTANT: It is recommended that all **BENOMYL** applications be preceded by an application of **MANCOZEB** at 200g/100 L water during the last week of October up to the 10th of November.		
Late cultivars; trees younger than 20 years which are growing vigorously	Benlate + mancozeb + mineral oil	50 g + 200 g + 500 ml	Apply as one full cover spray between 1 and 20 December.
Old, neglected trees with a history of high susceptibility	Benlate + mancozeb + mineral oil	75 g + 200 g + 500 ml OR 50 g + 200 g + 500 ml	Apply as one full cover spray between 1 and 20 December. Apply as a single full cover spray during the second week of November. Follow up with a mancozeb application during the first week of January.
	Split applications are recommended if problems are encountered in obtaining complete coverage	25 g + 200 g + 500 ml	First application during the second half of November. Second spray application during the first week of January.
Lemons	Benlate + mancozeb + mineral oil*	50 g + 200 g + 500 ml	Apply as a single full cover spray during the second week of November. Follow up with a mancozeb application during the first week of January.
	Mancozeb	200 g	Remove all fruit before commencing with the application of azoxystrobin. Apply mancozeb preventatively during September and October. Commence the treatment programme by applying as soon as possible after 100% petal drop.
	Azoxystrobin + Mancozeb/ Copper oxychloride + mineral oil	2× (20 ml + 150 g + 300 ml)	Follow-up after 21 days with the 1st application of azoxystrobin (approximately mid to end October) and repeat with a 2nd application of azoxystrobin six weeks

	Mancozeb	200 g	later (approximately end of November to beginning of December). If conditions remain favourable for infection, a further one to two applications of mancozeb should be made at 21 - 24 day intervals to provide protection during January and February.
Early cultivars	Benlate + mancozeb + mineral oil Split applications are also registered	50 g + 200 g + 500 ml	Apply as one full cover spray between 1 and 20 December.
		25 g + 200 g + 500 ml	First application during the second half of November. Second application during the first week of January.
Early cultivars	Carbendazim + mancozeb + mineral oil	27,5 ml + 200g + 500 ml	Apply a medium cover spray once between 1-20 December.
Late cultivars	Carbendazim + mancozeb + mineral oil	55 ml + 200g + 500 ml	**Trees younger than 20 years and growing vigorously**: Apply a medium cover spray once, between 1-20 December.
		55 ml + 200 g + 500 ml	**Old neglected trees with history of high susceptibility**: Apply a medium cover spray once between 15-30 November.
	Mancozeb	200 g	Follow up application during first week in January.
		OR	
	Carbendazim + mancozeb + mineral oil	82,5 ml + 200g + 500 ml	Apply medium cover spray between 1-20 December.

*The oil component in the treatment may have a detrimental effect on yield. Refer to RED SCALE in Chapter 3 on the use of mineral oils.

3 RESISTANCE OF BLACK SPOT TO THE BENZIMIDAZOLE FUNGICIDES

Fungi tend to develop resistance to systemic fungicides in a relatively short period because these materials are often very specific inhibitors, i.e., they affect one or a few sites of action only. Conventional contact fungicides such as copper, in contrast, are general inhibitors, thus making the development of resistant strains more difficult.

In the case of the benzimidazole group of fungicides, the first confirmed case of resistance to black spot was reported after a period of five years of extensive use in the industry. This occurred in 1981 in the Lowveld. Resistance

towards the benzimidazoles has spread to all citrus production areas in southern Africa, except for the Eastern and Western Cape provinces.

The development of resistance necessitates a change to an alternative programme which excludes this group of fungicides. If resistance is suspected (evidenced by poor control), infected fruit with virulent-spot lesions should be collected and forwarded to the Diagnostic Centre at CRI in Nelspruit for testing. (Consult the chapter on the CRI Diagnostic Centre in Section 5).

To minimise the risk of resistance developing, the following strategy is recommended:

- Use mixtures of contact and systemic fungicides, as each possesses a different mode of action.
- Do not use split applications but rather spray benzimidazoles such as Benlate once at 50 g than twice at 25 g/100 litres water.
- Do not plant lemons in areas where an abundance of inoculum is expected.

It has been demonstrated in field trials, that even after five years of non-use of benzimidazole fungicides, the resistant strains persist. Based on this experience, it is unlikely that these fungicides can be used again in the same plantings after the development of resistance.

4 ORGANISATION OF THE SPRAY PROGRAMME

4.1 Spray apparatus

Ensure that spray apparatus is in good working condition before the season begins. If mist blowers are to be used, they must be carefully calibrated. Ensure that a spray round can be completed in time with the apparatus available and allow time for possible hold-ups caused by rain or machinery breakdown.

4.2 Sequence in which orchards must be sprayed

Begin with the oldest Valencia orchards, and end the round with the early maturing cultivars. Retain the same spray sequence for subsequent spray rounds.

4.3 Harvesting of fruit

The general appearance of black spot symptoms on fruit in Valencia orchards early in the season indicates either resistance to the systemic fungicides or a basic error in the spray programme. This can lead to a rapid increase in uniform symptom expression, in such orchards, later in the season. This uniform occurrence of black spot must be differentiated from the early but sporadic occurrence of symptoms, which results from occasional fruit being missed during spraying. Endeavour to harvest these orchards as soon as possible in order to keep fruit loss to a minimum. This will also reduce the risk of post-harvest development of fruit lesions due to the fact that the fruit will be handled in the cold chain shortly after packing.

5 THE APPLICATION OF PLANT PROTECTION PRODUCTS

5.1 Coverage

Medium cover, film sprays are recommended. (Consult the chapter on the application of plant protection products in Chapter 2 of this volume). The objective is to cover each fruit thoroughly without wastage of material. This applies also to the systemic fungicides, which only penetrate where they make direct contact with the fruit surface at the time of treatment.

5.2 Effect of rain

If rain falls on sprayed trees, which have not yet dried, it is essential to respray them. If the spray material has dried, its efficacy will not be affected by rain. Bear in mind that when the humidity is high, trees will take a longer time to dry.