**INTRODUCTION**

Citrus greening disease is a major cause of crop and tree losses in most of the major citrus producing countries of the world viz. Asia, Brazil, USA and Africa. The disease is known by various names: Yellow shoot (huanglongbing) in China; likubin (decline) in Taiwan; dieback in India; leaf mottle in the Philippines; vein phloem degeneration in Indonesia; yellow branch, blotchy mottle, or greening in South Africa (Da Graa, 1991).

Citrus greening has had a devastating effect on citrus production in the North West-, Limpopo-, Mpumalanga- and KwaZulu Natal Provinces since it was first observed in 1928. Losses due to greening disease are not easy to assess. Total crop losses are evident if the entire tree is infected but it is possible that only sectors of a tree become affected and losses are small. Crop losses of 30-100% were recorded in some production regions in South Africa between 1932 to 1960. The incidence of the disease has declined slightly since the seventies but the effect of the disease still eliminated the commercial production of citrus in three major production areas: Tzaneen; White River, Brondal and Schagen areas.

**STATUS OF GREENING DISEASE IN SOUTH AFRICA**

The occurrence of greening disease can be divided into four major zones based on the presence and severity of the disease.

**Zone A:** where the highest incidence occurs, includes the Karin-White River, Hazyview, Brondal, Nelspruit, Tzaneen, Rustenburg, Mokopane and Zebediela areas, and certain magisterial districts in the Western Cape Province.

**Zone B:** where the incidence of greening is moderate, includes the Letebele, Letaba Valley, Lydenburg-Ohrigstad, Muden-Piet-ermaritzburg-Richmond areas, and the higher-lying areas of Swaziland.

**Zone C:** where the incidence of greening disease is low, includes the Kaapmuiden-MalehHectompmit, Groblersdal-Marble Hall areas, and large areas of Northern KwaZulu-Natal including the Nkwaleni Valley.

**Zone D:** includes areas where the disease does not occur, e.g. Citrusdal, Eastern and Northern Cape.

In most cases in the Zone C areas, the disease was introduced by the planting of infected trees that originated from nurseries in Zone A and B areas.

In the Western Cape, citrus greening was discovered in the Stellenbosch region during a survey that was conducted by Schwarz in 1967 (Schwartz, 1967). The presence of the disease in this area was confirmed in 1995. A survey on the occurrence and spread of the disease in the Western Cape was conducted during 2004. A follow-up survey in 2005 indicates that the disease has...
subsequently spread and is now established in a large portion of the citrus growing regions within the Western Cape (Fig. 1).

THE PATHOGEN AND TRANSMISSION

The organism associated with greening disease has been characterised as a gram-negative bacterium and named *Candidatus Liberobacter*. This organism is phloem-restricted and has not yet been isolated as a pure culture. Two distinct species of the organism have been recognised; the African form is named *Candidatus L. africanum* and the Asian form *Candidatus L. asiaticum*. The Asian form, which does not occur in South Africa, is heat sensitive with no symptoms occurring above 30°C, while the African form is heat sensitive with no symptoms occurring above 30°C.

Greening disease is transmitted by the citrus psylla, *Trioza erytreae*, (Fig. 2) whereas the Asian species is transmitted by the psyllid, *Diaphorina citri*. Greening is also graft transmissible but is not transmitted mechanically by means of cutting tools. Under ideal conditions the citrus psylla can become infected (or become a carrier) with the organism after an acquisition feeding period of eight hours and then transmit to healthy plant tissues after feeding for less than one hour. The rapid transmission rate, coupled with the ability of the insect vector to multiply extremely rapidly under favourable conditions, renders the effective control of the disease and the vector very difficult (Van den Berg 1990).

Citrus psylla is present in the majority of citrus production areas. The cool, high altitude production areas of the Limpopo Province are considered endemic and are particularly favourable for the development of this insect. In the hot, low-lying areas of the Limpopo Province, Mpumalanga, the Eastern Cape and Citrusdal areas of the Western Cape, little or no spread of the disease occurs as a result of the sporadic presence of the vector. The incidence of the insect is also low in endemic areas following high temperatures accompanied by low relative humidity. These conditions cause high mortality in egg and nymphal stages.

SYMPTOMS

All commercial cultivars and rootstocks are susceptible to greening disease. However, differences in tolerance to the disease occur between cultivars. Sweet oranges, mandarins and tangelos are very susceptible, with Minneola tangelo being the most susceptible of all commercially grown citrus cultivars. Citrus trees on *Poncirus trifoliata* rootstock and its hybrids appear to produce a higher percentage of greened fruit than on other rootstock cultivars. Once a tree has become infected it remains infected for its entire lifespan. During early summer, affected trees appear to improve in condition but as autumn and winter approach, affected sectors or branches of the trees are easily identified.

**Leaves**: Foliar symptoms are non-specific and can easily be confused with symptoms induced by root pathogens such as *Phytaphthora* spp. and *Fusarium* spp. or with symptoms of trace element deficiencies (Fig. 3). Foliar symptoms vary from vein chlorosis ("yellow vein") to a "blotchy-mottle" of part or all of the leaf (Fig. 4). Leaves showing this latter symptom are mostly the larger leaves on the lower parts of branches, those on short branches inside the canopy, and those on more vigorous shoots that develop during the late summer flush. On chronically infected trees the mature leaves are small, upright and frequently exhibit signs of zinc and iron deficiency. These leaves may remain pale and turn green along the main and lateral veins. Leaves on affected branches often feel leathery as a result of starch accumulation in the tissues. Chlorotic leaves usually abscise and the associated twigs die back. The blotchy-mottle symptoms arise as a result of damage to the chloroplasts caused indirectly by infection. Once the nymphs have hatched from eggs that are normally laid on the edge of the leaves, the nymphs move to the lower side of the leaf where they attach themselves and start forming an indentation that they feed in. On the upper leaf surface these indentations appear as bumps, the classic psylla symptom (Fig. 5).
Fruit: Symptoms of greening disease on affected fruit are diagnostically more reliable than foliar symptoms. Fruit are affected in various ways. When they reach 10 to 20 mm in diameter they can become lopsided and mature only on one side, the immature side remaining green when the fruit ripens (Fig. 6). Seed is either absent or abortive in the green side of the fruit (Fig. 7).

This type of fruit is found more frequently in the cool citrus production areas. Other normally shaped fruit can attain full size but may fail to colour properly and will remain a green or yellow colour and drop before harvest. The seeds in these fruit are mostly sterile. When applying pressure with the thumb to the green side of an infected fruit, a silvery tinge usually appears in the depressed area. The juice of affected fruit is low in soluble solids, high in acid and has a bitter, salty taste, making it unmarketable.

Young trees: When trees become infected in the nursery or before reaching bearing age, all new growth tends to become systemically infected and the trees fail to come into production.

Older trees: Systemic spread in older trees is slow and the greening organism tends to remain localised in the branches infected initially. Movement from branch to branch in these trees is usually as a result of separate transmissions by the vector and not by systemic movement.

Symptoms may be observed throughout the tree, depending on the age when the tree became infected. Foliar symptoms are often absent during late spring and summer, but as winter approaches symptoms become more defined and are easier to detect. These symptoms can often be confused with so-called "winter-chlorosis". Leaf drop usually occurs resulting in early flushing. Early and excessive blossoming are also frequently observed on affected branches but they usually bear poor crops (Fig. 8).

Cultural practices: Disease-free nursery trees. Only plant trees supplied by Citrus Improvement Programme (CIP) accredited nurseries in greening disease-free areas. The Agricultural Pest Act, 1983 (Act No. 36 of 1983) as amended, states that no citrus plant material is permitted to be moved from the following magisterial districts, Caledon, Hermanus, Paarl, Robertson, Somerset West, Stellenbosch and Swellendam, to the Eastern Cape and to the following magisterial districts in the Western Cape: Beaufort West, Bredasdorp, Calitzdorp, Ceres, Clanwilliam, George, Helderberg, Hopefield, Knysna, Kuilsrivier, Ladismith, Laingsburg, Mitchells Plain, Montagu, Moorreesburg, Mosselbay, Murraysburg, Oudtshoorn, Piketberg, Prins Albert, Riversdale, Simons Town, Tulbagh, Uniondale, Van Rynsdorp, Vredenburg, Vredendal, Worcester and Wynberg.

Eradiation of infected plant material. Inspect orchards during the winter months before harvest for signs of greening disease infection and mark the infected branches. Trees up to five years of age that have 50% or more of their branches infested should be removed. Infected branches should be removed in the remaining trees.

Trees 10 years and older which have 40% and less of the

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**Fig. 5.** Typical psylla symptoms on the leaves.

**Fig. 6.** Healthy (left) and greening infected fruit (right).
canopy showing symptoms should have the affected branches removed. Pruning stimulates vegetative growth and this, in turn, attracts psylla, particularly when growth occurs on the cooler, southern side of the tree. This shady side also offers an ideal habitat for psylla breeding. Pruning should therefore be timed so that the regrowth coincides with a treatment that will control psylla. When an entire main branch is infected it should be removed completely at the point where it originates on the trunk. When a secondary branch is infected it should be removed at the main branch at its point of origin. To inhibit the regrowth of shoots at the pruning wounds and thereby remove potential psylla breeding sites, the wounds can be treated with one part NAA (Planofix) plus six parts narrow range oil (Orchex, etc).

The removal of neglected and infected orchards, especially lemon orchards, is essential to reduce the inoculum in greening-infected areas. Lemon orchards are more susceptible to psylla infection due to their natural growing characteristics and can therefore serve as a source of infection for the rest of the area.

**Biological:** Indirectly, biological control of greening disease has been successful in Réunion by introducing the parasitoid wasps *Tetrastichus dryi* and *Psyllaephagus pulcinatus*, which control the vector. These parasitoids were collected in South Africa where they are the major parasitoids of *T. erytreae* (van den Berg, 1990). Unfortunately a survey of parasitoids of psylla in South Africa showed that none of them reduced densities low enough to prevent the spread of greening due to the presence of hyperparasitoids. The parasitoids are much more effective in Réunion because the hyperparasitoids were not introduced.

**Vector Control:** Psylla control is the most important facet of controlling greening disease. Without efficient psylla control the other measures become redundant.

The following insecticides are registered for psylla control and should be utilised to reduce the presence of citrus psylla in citrus orchards:
- Soil applications of Temik (G) 12.5 g/m² can protect the plant for 25 days. Conidio can give 52 days protection.
- Stem applications with Mospilan 42 days and Citrimet 18 days.
- Foliar - Registered insecticides.

**CONCLUSION**

The use of disease-free planting material certified by the CIP and grown in psylla-free nurseries; the use of systemic insecticides applied to control the vector; and the reduction of inoculum if a region by removing all neglected and diseased trees (especially lemon trees) will enable citrus producers to continue producing export citrus in areas where citrus greening disease is present. An intensive coordinated greening management approach by all the role players in the Western Cape, viz., growers, consultants and chemical representatives is essential to ensure export quality fruit.

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**REFERENCES CITED**

