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Greening Disease of Sweet Orange in South Africa

GREENING DISEASE, a mysterious malady involving arrested development of entire trees or parts thereof together with a wide range of chlorotic leaf symptoms as well as poor crops of undersized, usually lop-sided, and poorly colored fruit of inferior quality, has been known to affect sweet orange [*Citrus sinensis* (L.) Osbeck] in parts of South Africa since 1929.

During the periods 1932-36 and 1939-46, severe crop losses were experienced in the White River and Plaston areas of the Eastern Transvaal, but the disease was of little importance elsewhere in South Africa. Since 1958, however, greening has also resulted in severe crop losses in many sweet orange orchards in two other regions where it has been known to occur for many years, namely Rustenburg (Western Transvaal) and Tzaneen-Politsi (Northern Transvaal). Greening has rendered approximately 100,000 sweet orange trees, mostly Valencia and Washington Navel on rough lemon (*C. jambhiri* Lushington) rootstock, commercially unprofitable in the three citrus areas referred to. A further disturbing feature is the occurrence of the disease in many other citrus regions hitherto regarded as free thereof. Although resembling stubborn disease in several respects, greening is believed to be a separate malady, which so far appears to be confined to certain more or less well-defined citrus regions of southern Africa.

Host Range and Symptomatology

Greening is a disease affecting primarily the sweet orange. Seedlings, nucellar lines, and old lines of all major commercial varieties appear to

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be equally susceptible, although the Valencia variety shows more pronounced foliar symptoms than the Washington Navel. Marloth (3) reports that greening occurs as frequently at Nelspruit in Valencia orange on rough lemon rootstocks as on sweet orange rootstock, and that it has been observed in this variety on trifoliolate orange [*Poncirus trifoliata* (L.) Raf.] rootstock.

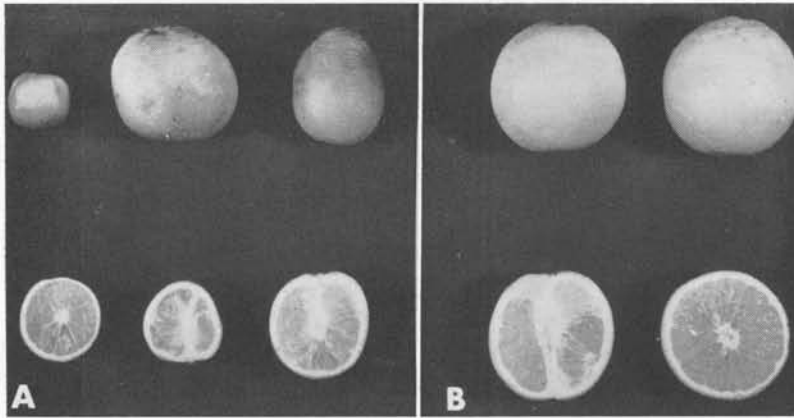


FIGURE 1. A. Greened fruit from a young Valencia orange tree on rough lemon rootstock. B. Normal fruit from the same tree.

Many other species and varieties of citrus in South Africa develop symptoms resembling those of greening and they are usually accompanied by severe decline of the tree. Whether these symptoms have the same cause as greening has not been definitely established, due largely to the fact that many of the species and varieties are also sensitive to tristeza virus, which is present in practically all field-grown citrus in South Africa.

Inasmuch as experimental work on greening has been conducted mainly with the sweet orange, only the symptoms shown by this species of citrus will be described.

GENERAL TREE EFFECTS.—Greening usually causes considerable stunting, leaf and fruit drop, and twig dieback, depending largely on the extent to which the tree is affected. Severely diseased trees are badly stunted, unthrifty, usually rather sparsely foliated, and produce poor crops of predominantly greened, worthless fruit. On the other hand, if only a sector of the tree is affected, a condition commonly found in many orchards, then only the affected parts show typical symptoms while the rest of the tree exhibits normal growth and produces normal

fruit of good quality. Diseased trees or parts thereof are at times inclined to heavy leaf drop, often followed by out-of-season growth flushes and blossoming. Severely diseased trees usually have poorly developed root systems, with relatively few fibrous roots. Generally, affected trees appear unthrifty and have a somewhat lighter color than healthy ones. They also tend to show general starvation symptoms not unlike those due to *tristeza* (1).

Apart from seasonal fluctuations in crop losses, the most baffling feature of greening is its variable occurrence in individual trees as well as its peculiar distribution within and between orchards in the three main centers previously referred to. Thus individual trees can be classed roughly into four categories. (a) The entire tree is affected. Such trees are stunted, sparsely foliated, and chlorotic. Crops are poor and fruit predominantly greened. (b) The greater part of the tree is affected, but small branches, or even a sector of the tree, remain healthy and normal. Demarcation between normal and diseased parts of the tree is usually well defined, but in some instances normal and greened fruit occur together. (c) The largest part of the tree remains normal in all respects, with only a single sector, or perhaps a few small or large branches, being affected. Here too, there is usually a sharp demarcation between diseased and healthy parts of the tree. (d) The whole tree is normal except for a few small, usually isolated diseased twigs or small branches. In some cases, trees carry only a few greened fruit, but otherwise appear normal with hardly any of the foliar symptoms that are usually associated with the disease.

The occurrence and distribution of greening within and between orchards in severely affected areas represent an equally interesting and baffling picture. In such areas are to be found sweet orange orchards of considerable size in which practically every tree is severely affected, resulting in crop losses of 90 per cent or more. Adjacent orchards, frequently separated by only a roadway or windbreak, may be only slightly affected with insignificant crop losses. Between these two extremes are to be found almost all possible variations in incidence of greening. Thus in one 10-year-old Valencia orchard on rough lemon rootstock at Groblersdal, Transvaal, only one severely greened tree was found in an orchard of 250 trees.

FOLIAR SYMPTOMS.—Greening is invariably accompanied by a great diversity of foliar chloroses, of which a type of mottle leaf resembling that due to zinc deficiency is often the predominant one. However,

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chloroses resembling those resulting from deficiencies of iron, manganese, calcium, sulphur, and boron, and generally accompanied by a reduction in leaf size are also quite common. Occasionally, greened fruits are produced on twigs with no abnormal foliar symptoms. Initially, young leaves from new growth cycles appear to be normal, except for a pale-green color. Gradually, however, they tend to assume an upright position, to become leathery to the touch, and also to develop a dull, olive green color. In time the veins become prominent by assuming a yellowish color somewhat resembling the effects of girdling.

Mature leaves of sweet orange and lemon may develop not only the various types of chlorosis referred to but also irregular chlorotic patches between the main veins alongside the midrib, resulting in a blotchy, almost variegated type of chlorosis. In the case of severely affected twigs, premature leaf drop occurs at times, resulting in out-of-season blossoming. Subsequent growth flushes on such twigs tend to be spindly and weak with small, chlorotic leaves. Many of the latter may be almost entirely devoid of chlorophyll, except for occasional circular green spots distributed at random on such leaves. Fairly severe twig dieback, at times accompanied by multiple bud formation, is another characteristic feature of badly diseased trees. In the opinion of the authors, the foliar symptoms referred to are specific for greening, and can therefore be used as a reliable method of diagnosing the disease in the field and elsewhere.

FRUIT SYMPTOMS.—In the past, most research workers have regarded the underdeveloped, usually lopsided, small, and poorly colored fruit with curved columella as the most reliable diagnostic symptom of greening, especially in the case of sweet orange varieties. Color is usually unequally distributed; sides exposed to direct sunlight develop full color, whereas the remainder of the fruit remains a dull, olive green, with only a touch of orange. When pressure is exerted on such fruit, a greyish-white, waxy deposit appears on the surface of the rind.

Many greened fruit develop high shoulders at the stem end with thick, puffy rinds. Vascular bundles stand out prominently in the albedo, usually having a yellowish-brown color. "Blue albedo" as reported for stubborn disease (2) occurs occasionally, but cannot be regarded as typical of greening. The same applies to acorn fruit, which are very rarely found on trees affected by greening.

The factors responsible for ultimate development of greening probably commence to operate at an early stage of fruit development. Apart from the normal November drop, there is a continuous and premature shedding of greened fruit until the normal time of harvesting, although

all affected fruit do not necessarily drop prematurely. Diseased Valencia and midseason varieties of sweet orange often show browning and death of the fruit peduncle a few weeks before the normal time of harvesting. This results in small, highly colored fruit, which may remain on the tree for shorter or longer periods. Gradually this dieback spreads away from the button end of the fruit, thus causing the death of many twigs and smaller branches.

Greened fruit are of no commercial value since they are usually low in juice content and soluble solids and fairly high in acid content. In addition, the juice cannot be used for processing either because it imparts an objectionable bitter-salty flavor to the canned product.

The majority of seeds in greened fruit remain small, dark colored, and underdeveloped, although some normal seeds do develop in Valencia and other varieties of sweet orange. Nucellar seedlings raised from severely diseased Valencia orange trees appear to grow normally, but have not produced any fruits so far.

Evidence that Greening Is Caused by a Transmissible Virus

Initially, greening was of a restricted and localized character, and confined largely to acid soils of low general fertility, base-exchange capacity, and exchangeable cations, especially calcium and magnesium. These considerations, together with the wide range of apparent nutritional disorders associated with the malady, led many research workers to believe that greening represented a form of malnutrition. Detailed nutritional studies, including soil and plant analyses, fertilizer trials, and foliar sprays comprising all essential plant nutrients, as well as sand culture experiments, have however consistently failed to reproduce greening. In recent years greening has also appeared in areas having alkaline soils of exceptional fertility, where citrus has been successfully grown for many years without any fertilization whatever. These considerations would tend to exclude the possibility that nutrition bears any direct relation to the greening disease.

Oberholzer and Hofmeyr (4) first suggested that greening is a transmissible virus disease. Evidence in support thereof may be summarized.

VEGETATIVE PROPAGATIONS FROM DISEASED TREES.—Greening is not readily perpetuated in daughter trees by means of vegetative propagation. When raised from severely greened trees by budding or grafting onto rough lemon rootstock, daughter trees may or may not exhibit

symptoms of greening, especially in the case of budding. When top-grafting is used, as many as 50 per cent of daughter trees show typical foliar symptoms of greening. Trees with symptoms of greening are occasionally found in the nursery row in commercial nurseries. Attempts to propagate diseased trees from cuttings have not been successful.

TRANSMISSION STUDIES.—Transmission studies on greening have yielded variable and erratic results, both in the greenhouse and in the field. The inoculum consisted of bark patches, buds, and scions of diseased sweet orange trees grafted onto seedlings of sweet orange in the greenhouse as well as onto healthy Valencia orange trees in the open. No transmission was obtained by using bark strips as a source of inoculum. Some transmission was obtained by using buds as inoculum sources, both in the greenhouse and in the open. Best results were again obtained in the greenhouse using budsticks containing two or three buds and top grafting them onto healthy sweet orange seedlings. Typical foliar symptoms of greening developed on both seedling and scion approximately one year later. In one field experiment, a healthy Valencia orange tree, which was inoculated with buds from a severely greened Valencia orange tree, produced typically greened fruits on three inoculated branches; greening symptoms were still confined to these three branches six years after inoculation.

NATURAL SPREAD BY MEANS OF AN INSECT VECTOR.—Since 1957, general observations and experience have strongly suggested that greening is capable of natural spread in the field, especially in those areas where the disease has assumed serious proportions. In this respect it has been suggested from several different quarters that the citrus psylla [*Trioza erytreae* (Del Guercio)] may act as a natural vector of greening. In the past, this insect has been troublesome only in citrus nurseries. Since 1957 however, and especially following the continued use of parathion sprays for red scale control, it has assumed importance as a serious pest in many citrus orchards, especially in somewhat cooler areas at altitudes exceeding 3,000 feet above sea level, such as Rustenburg, White River, and Tzaneen. As indicated earlier, these are the main areas where greening has so far caused the most severe crop losses. It is significant that the citrus psylla is seldom found in great numbers in hot, dry regions at low altitudes, where greening is either absent, or of no commercial significance. Furthermore, this particular species of citrus psylla does not occur in any of the other major citrus regions of the world where greening is apparently also unknown (5).

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Strong evidence in support of natural field spread of greening has been experienced with the establishment of a citrus variety orchard on the Experimental Farm of the University of Pretoria. The orchard, comprising old as well as nucellar lines of the common commercial varieties of citrus on rough lemon rootstock, was established during 1949-52. All trees, especially those of sweet orange, made exceptionally good growth, exhibiting no symptoms of greening. In order to have material readily available for glasshouse studies, several sources of greened material, including two severely diseased Valencia orange trees from the Rustenburg area, were established alongside the variety orchard during 1953. At that time, no evidence was available that greening could spread through the air. Soon after the establishment of the greened material, the disease made its appearance in the experimental trees; by 1958 all sweet orange trees were severely affected, whereas serious decline phenomena also occurred among lemon, grapefruit, and mandarin trees. Of special significance is the fact that the citrus psylla had been a serious pest almost from the time the orchard was established. Furthermore, since 1957 it has become utterly impossible to produce any normal nursery trees in the vicinity of this orchard since such trees invariably become stunted in growth and exhibit typical foliar symptoms of greening. Meanwhile, identical stock-scion combinations have continued to make normal growth inside a glasshouse situated adjacent to the experimental orchard. These experiences strongly support the view that the citrus psylla acts as a vector of greening in the field.

NOTE.—Recent work by Dr. A. P. D. McClean, Institute for Plant Protection, Department of Agricultural Technical Services, has proved conclusively that greening is a transmissible virus disease; and that the citrus psylla acts as a natural vector thereof.

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