THE INFLUENCE OF ROOTSTOCK ON GROWTH OF BUDGRAFTED CITRUS

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SUMMARY

IN budded citrus the root-stock is known to influence the growth of the scion. Symptoms of stock-scion incompatibility may appear early in the nursery beds, or may be delayed over a period of years in the orchard if the soil and climatic conditions are favourable for healthy growth of citrus.

In the mid-country semi-dry area at Malpotha all varieties of citrus grow well on rough lemon, an invigorating stock, but on the European lemon which grows to perfection at this elevation of 3,500 feet, budgrafts of sweet orange, mandarin and Seedless Tahiti lime turn chlorotic and die back in the nursery beds. The roots too die back from the tips. But the unbudded lemon seedlings and lemon budgrafts on lemon stock make healthy growth. The diseased condition is probably not due to a virus as starch is present in the pith and phloem tissues above and below the bud unions of both healthy and diseased plants.

Both grapefruit and sweet orange grow well on seedling sweet orange and rough lemon stocks at Peradeniya, but on sour orange the tendency is for the scion to become chlorotic and stunted. Buds from these chlorotic shoots produced healthy vigorous plants when budded on rough lemon and sweet orange stocks. The incidence of chlorosis and die-back on citrus budgrafts on sour orange stock appears to be delayed at Teldeniya, Moneragala and Bibile where soil and climatic conditions favour the healthy growth of citrus.

INTRODUCTION

Commercial citrus varieties in most parts of the world are propagated on a root-stock. The principal root-stocks used for the purpose are sour orange (*Citrus aurantium L.*), rough lemon (*Citrus jambhiri Lush.*), sweet orange (*Citrus sinensis Osbeck*), and trifoliate orange (*Poncirus trifoliata*).

The sour orange has been used extensively as a root-stock for citrus in the United States of America, Spain, Palestine and other Mediterranean countries. According to Hume (8) over 75 per cent. of the world's citrus was at one time on this stock because of its high degree of resistance to brown rot gummosis. In recent years, however, it has become a failure as a root-stock for citrus in South America (10), parts of California (4, 6) and Australia (3) owing to the incidence of a virus disease which causes the death of sweet orange trees propagated on it. Over 8 million trees of this stock-scion

combination are estimated to have been killed in South America since 1932 by this disease which is known there as "Tristeza", a Portuguese word meaning melancholy or sadness. Several sweet orange orchards have also gone out of production in California and Victoria since 1941 owing to the ravages of "Quick Decline" and "Bud-union Decline" which are believed to be very similar to "Tristeza" in many respects. The virus appears to continue its destructive work unchecked and is a potential menace to citrus on sour orange stock all over the world.

The rough lemon is used almost exclusively as root-stock for citrus in South Africa, parts of Australia, India, Java and Florida. Citrus varieties budgrafted on it are not affected by "Quick Decline" or "Tristeza", but it is not so resistant to brown rot gummosis as sour orange.

The sweet orange has become popular as a root-stock in place of sour orange because of its resistance to "Quick Decline", but it is susceptible to brown rot gummosis which, however, is now easy to control owing to improvement in orchard sanitation.

The use of the deciduous trifoliate orange as a root-stock is restricted to colder areas as it is inherently resistant to frost. It makes a good stock for the Satsuma mandarin which develops the best flavour on it, but with most citrus varieties stock overgrowth is very pronounced at the bud-union.

None of these citrus species makes an ideal root-stock for commercial varieties, and efforts are being made in nearly every citrus-producing country to develop suitable root-stocks for local requirements. In Ceylon the rough lemon, sour orange and sweet orange have been under trial for sometime as root-stocks (11), and more recently the sour lime (*Citrus aurantifolia*), European lemon (*Citrus limon L.*) and *Patharan* (*Citrus megaloxycarpa var. penivesiculata. Lush.*) were included for study.

EXPERIMENTAL

In the citrus stock-scion trial set down at Moneragala in November, 1945, rough lemon, sour orange and sweet orange were used as root-stocks in combination with Bibile and Vavuniya sweet orange scion varieties in a Randomized Block lay out with 4 replications and 4 plants per plot. Unbudded nucellar seedlings of the two orange varieties were also included in the trial, making a total of 128 trees.

In the root-stock trial at Peradeniya, only the Vavuniya sweet orange variety was used as unbudded nucellar seedlings and as budgrafts on rough lemon, sour orange, and sweet orange stocks in randomized single-tree plots replicated 6 times. The plants were transplanted into the permanent site from nursery beds in June, 1945.

Besides field trials several hundreds of nursery stock plants of these varieties as well as sour lime, European lemon and *Patharan* were budgrafted to Bibile and Vavuniya sweet orange, Nagpur Santra mandarin and Eureka lemon in the nurseries at Peradeniya, Bibile, Moneragala, Teldeniya, and Malpotha, and allowed to grow in nursery beds for observation.

RECORDS OF GROWTH

Measurements of girth were taken at fixed points 6 cm. above and below the bud-union. In the case of seedling plants measurements were taken 6 cm. above and below the point at which they would have been normally budgrafted.

CITRUS STOCK-SCION TRIAL AT MONERAGALA

The analysis of variance of stock and scion girth measurements recorded on September 15, 1948, is given in Appendix I. The mean values for girth are given in Table I.

TABLE I

	Stock girth in inches	*Scion girth in inches*
Rough lemon	11·30	9·57
Sweet orange	8·88	8·06
Nucellar sweet orange seedling	8·61	8·12
Sour orange	8·17	7·12

Rough lemon is significantly bigger than the others both in stock girth and its invigorating effect on the scion as reflected by scion girth. The differences in girth between the sweet orange stock, the unbudded sweet orange seedling and sour orange stock are not statistically significant, but in the stock effect on scion as measured by scion girth both sweet orange stock and the unbudded sweet orange seedling, which do not differ significantly from each other, give higher values than the sour orange.

None of these varieties has yet developed symptoms of chlorosis and die-back on the sour orange, and it remains to be seen whether they will continue to make healthy growth on this stock at Moneragala.

ROOT-STOCK TRIAL AT PERADENIYA

Measurements of stock and scion diameters were taken on September 10, 1948. The mean values are given in Table II and the analysis of variance in Appendix II.

TABLE II

	Stock Diameter in Cm.	*Scion Diameter in Cm.*
Rough lemon	8·17	6·53
Sweet orange	5·80	5·05
Nucellar sweet orange seedling	5·60	4·92
Sour orange	3·40	3·15

The rough lemon is again significantly bigger than the others both in stock diameter and in scion diameter. The differences between sweet orange stock and the unbudded nucellar sweet orange seedling are not statistically significant as may be expected, but the sour orange gives significantly lower values than the others for both stock diameter and scion diameter. Most of the plants on the sour orange stock were stunted and chlorotic, a few were already dead in the border rows.

NURSERY TRIALS

In nearly every case the growth of sweet orange on rough lemon was vigorous and healthy. Hardly any symptoms of chlorosis developed on the plants in the nursery or in the field trials. The growth of the sweet orange varieties on sweet orange stocks was also normal both in the nursery and the field. Even all the varieties of grapefruit—Marsh seedless Thomson, seedless, Cecily seedless, Walters, Ellen, Foster McCarthy and Triumph budgrafted on sweet orange in the grapefruit stock-scion trial at Peradeniya continued to make healthy growth.

Plate 1.—Six year old Marsh Seedless grapefruit on sour orange stock at Peradeniya. Note unhealthy stunted growth and die-back of the twigs.

But on the sour orange stocks in the nursery at Peradeniya the growth of sweet orange and grapefruit was variable. Most of the plants developed symptoms of chlorosis and mottle leaf with the first flush and showed a tendency to remain stunted. Some flowered and set fruit prematurely in the nursery beds. Those that remained healthy grew well only for about a year or two when planted out in the field (Plate 1). The incidence of chlorosis was however not very general in the nurseries at Teldeniya, Moneragala and Bibile where soil and climatic conditions appear to favour the healthy growth of citrus. Nevertheless, when the apparently healthy plants were planted out in the field at Teldeniya for observation, nearly all of them developed symptoms of chlorosis and died back within three to four years. Budgrafts of the same varieties on rough lemon stock inter-planted in the same area continued to make healthy growth and were very productive. Several grapefruit trees on sour orange stock in the stock-scion trial at Hingurakgoda are also considerably dwarfed and show characteristic scion over-growth although they continue to survive.

Sour lime seedlings were tried as root-stocks for sweet orange in the nurseries at Bibile and Moneragala as they are easy to raise in very large numbers and exhibit appreciable resistance to drought. Most of them were successfully budded to Bibile and Vavuniya sweet orange, but after the tops were cut off to force the scion buds the bark opposite the bud patch began to die-back from the cut end. In many cases the die-back was presumably arrested by the growth of the scion which helped to stimulate callus formation along the margins of the bark bordering the dead surface. No such die-back was to be seen on comparable rough lemon and sweet orange stocks budded in the adjoining nursery beds.

Seedlings of the European lemon which grows well up-country were interplanted with rough lemon stocks in nursery beds at Malpotha which is about 3,500 feet above sea level and budded separately to Washington Navel orange, Nagpur Santra mandarin and Eureka lemon. Growth of all the varieties was normal on the rough lemon, but on the lemon stocks only Eureka lemon made normal vigorous growth. The first flush produced by the sweet orange and mandarin buds turned chlorotic and died back after shedding the leaves (Plate 2). Examination of the root systems showed progressive dying back of the tap roots and laterals from the tips. The bark was sloughing off from the dead portions of the roots which were discoloured bluish grey. The unbudded lemon seedlings also made normal growth like the lemon budgrafts and showed no die-back of the roots.

The Patharan is also reputed to be drought resistant like the rough lemon which has a fibrous root system, but it is difficult to transplant successfully from nursery beds after budgrafting as it has a long tap-root with hardly any laterals. The scion buds of the common citrus varieties do not "take" readily on it owing to the copious flow of gum from the exposed tissues during long dry spells. Nevertheless, trees of Marsh seedless and Walters grapefruit on this stock planted ten years ago on rocky land in the semi-dry zone at Nalanda have grown well without irrigation and are very productive. Other citrus varieties have been raised on this stock for trial next season.

BUDGRAFTING TRIALS

Buds were taken from the chlorotic shoots of Vavuniya sweet orange on sour orange stock and from the healthy shoots of the same variety on rough

lemon and sweet orange in the trial at Peradeniya, and budded on sour orange, rough lemon and sweet orange stocks in a nursery nearby. The growth of all the buds including those from the chlorotic shoots was normal and of healthy green colour on all the stocks except sour orange on which scion growth continued to be chlorotic and sickly.

Similarly, chlorotic buds from Washington Navel orange grafts on European lemon stocks at Malpotha were found to make healthy growth when inserted on rough lemon stocks.

DISCUSSION

From the studies made so far it appears that even the local varieties of sweet orange such as Bibile and Vavuniya, which are of seedling origin and inherently more vigorous than many of the imported varieties, make unhealthy growth on the sour orange, and that the incidence of chlorotic symptoms on plants of this stock-scion combination is delayed in areas where soil and climatic conditions are favourable for healthy growth of citrus. The symptoms appear earlier in the wet zone at Peradeniya where even seedling citrus trees tend to become chlorotic within a short period if neglected.

The failure of the sweet orange on sour orange stock was first observed in South Africa as far back as 1899 (14). The stock would, however, make healthy growth and bear normal crop if allowed to grow unbudded, and so would the commercial lemon budgrafted on it. But sweet orange and, to a less extent, grapefruit and mandarin would fail to grow into healthy trees when budgrafted on it. The trees either died quickly in the nursery or within a short period after planting out. Those that survived were much dwarfed and worthless as producers. The failure was described as stock-scion incompatibility. The commercial lemon, certain acid limes, and to some extent the grapefruit, were also found to behave more or less like the sour orange when used as root-stocks.

Similar stock-scion incompatibility was observed in Java by Toxopeus (13) who thought that the sweet orange scion produced some substance which was toxic to the sour orange stock. Oberholzer (9) has now shown that a virus is probably responsible for the failure of sour orange as a root stock in South Africa. He first produced healthy budgrafts of Valencia orange and Triumph grapefruit on sour orange and lemon stocks by using budwood from seedlings of nucellar origin which are believed to be vigorous and free from virus infection. These seedlings come true to type since they develop from vegetative buds of the nucellus which consists only of maternal tissue. The healthy budgrafts were found to stop growth and develop chlorotic symptoms when buds of the same scion varieties taken from apparently healthy budded trees in the orchard were inserted into the root-stock or the scion. The virus seems to have been able to maintain itself in the sweet orange trees on rough lemon and sweet orange stocks in the orchard without showing any characteristic symptoms.

Similar transmission experiments have been carried out in California by Fawcett and Wallace (7) who showed that sweet orange trees on sweet orange stocks could become infected in the orchard and serve as carriers of virus in a latent form while remaining symptomless. McAlpin *et al.* (3) working in Victoria, Australia, have also found that buds from healthy

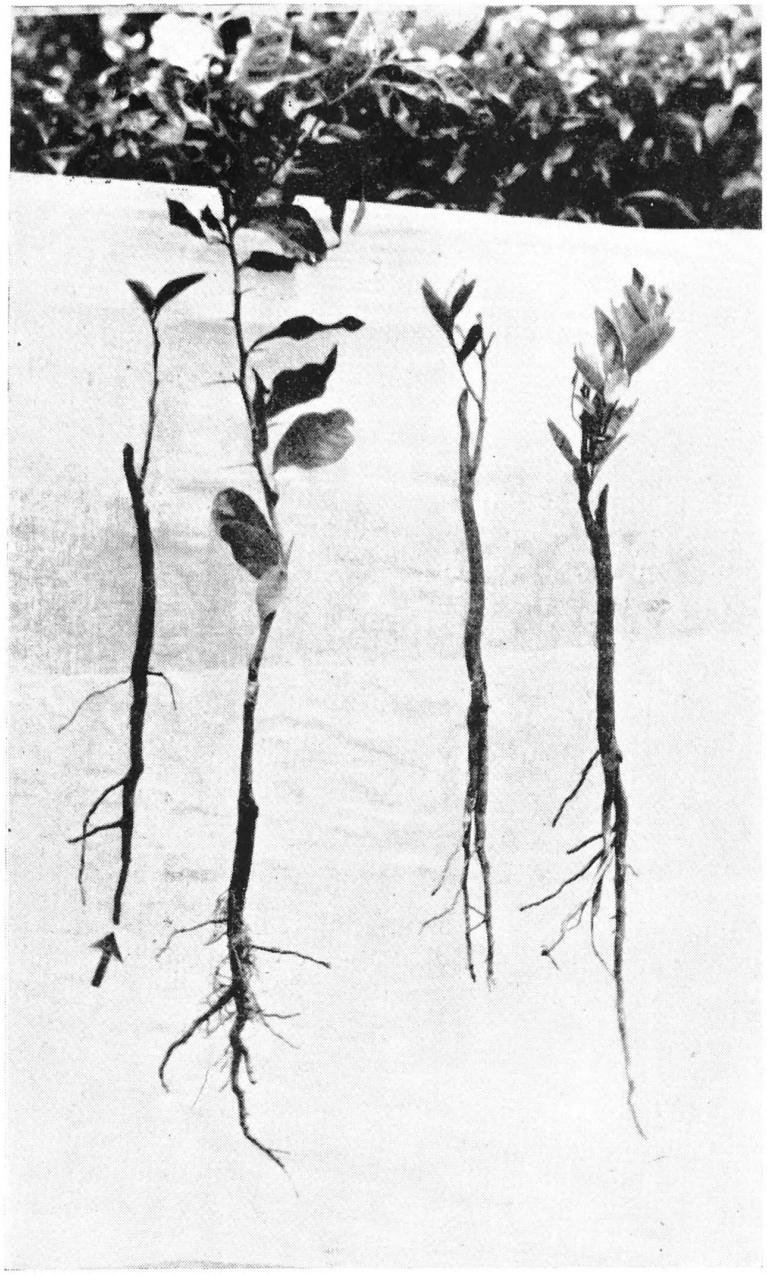

Plate 2.—Citrus budgrafts on European lemon stock at Malpotha nursery. Note vigorous growth of Eureka lemon (second from left) and unhealthy growth of Washington Naval orange (Extreme right) and Nagpur Santra mandarin.

Washington Navel tree on rough lemon developed symptoms of "bud-union decline" when worked on sour orange stock, but gave healthy trees on sweet orange stock.

The theory originally stated by Bitancourt (1) and elaborated by Webber (15) is that the virus could be present in sweet orange, mandarin and grapefruit without showing characteristic symptoms, but its action and development in the unbudded sour orange or lemon is probably inhibited by some product of metabolism in the foliage. That accounts for the healthy growth of the unbudded plants as well as suckers from the root-stock of budgrafts. But when used as a root-stock without its own foliage the virus from the infected sweet orange top is believed to cause the break-down of the sour orange sieve tubes below the bud-union.

Schneider (12) has shown by histological studies that degeneration of the sieve tubes occurs in the bark of the sour orange stock just at or below the bud-union as a result of which the translocation of starch to the roots is apparently restricted and the roots are starved after they use up the reserve food. This causes a progressive die-back of the roots from the tip towards the base.

The starch disappears almost completely from the roots of trees which are about to develop symptoms of "Quick Decline" (5) or "Bud-Union Decline" (3). First the bark and later the wood of the rootlets become devoid of starch which then disappears all along the large roots from the tip to the base. In acute cases the entire root-stock is depleted of starch right up to the bud-union. The loss of starch from roots of citrus is not usually associated with fungus and bacterial diseases or nematode attack.

The starch content of the bark and the wood above the bud-union may remain normal or even higher than that of the healthy trees. Nevertheless, very often trees which have been on the decline for some period and have reached a stage of unthrifty equilibrium may show approximately normal starch content in the root-stock. The starch test is therefore not always reliable in such cases.

The presence of starch is easily demonstrated by application of aqueous solution of iodine with a camel hair brush on the lightly scraped bark or wood. Any tissue containing starch will turn blue or even black according to the amount present. It has been shown by Cameron (2) that starch is present at all times in the wood of healthy citrus roots.

All citrus plants on rough lemon and sweet orange stocks in the nursery and field trials at Peradeniya and elsewhere were found to contain starch in the bark and wood both above and below the bud-union. But some of the grapefruit plants on sour orange stock in the nursery at Peradeniya were found to be devoid of starch below the bud-union although the root system consisted of a long well developed tap-root and several laterals (Plate 3). Nevertheless, in many Vavuniya sweet orange grafts on sour orange stocks which had remained stunted and chlorotic for about 2 years in the nursery at Peradeniya, starch was found to be present in the wood of the main taproot.

Starch was also present both above and below the bud-union of many chlorotic Washington Navel and Nagpur Santra mandarin plants on commercial lemon stock at Malpotha. There were, however, some healthy lemon

plants in active state of growth which contained no starch in the roots. Preliminary examination of sections of bark and wood above and below the bud-union has not shown any characteristic symptoms of break-down of phloem tissues, and the evidence available so far is not sufficiently conclusive to prove that the failure of sweet orange, grapefruit aud mandarin on sour orange and commercial lemon in most parts of the Island is due to a virus. Further investigations are being made in collaboration with the Plant Pathologist.

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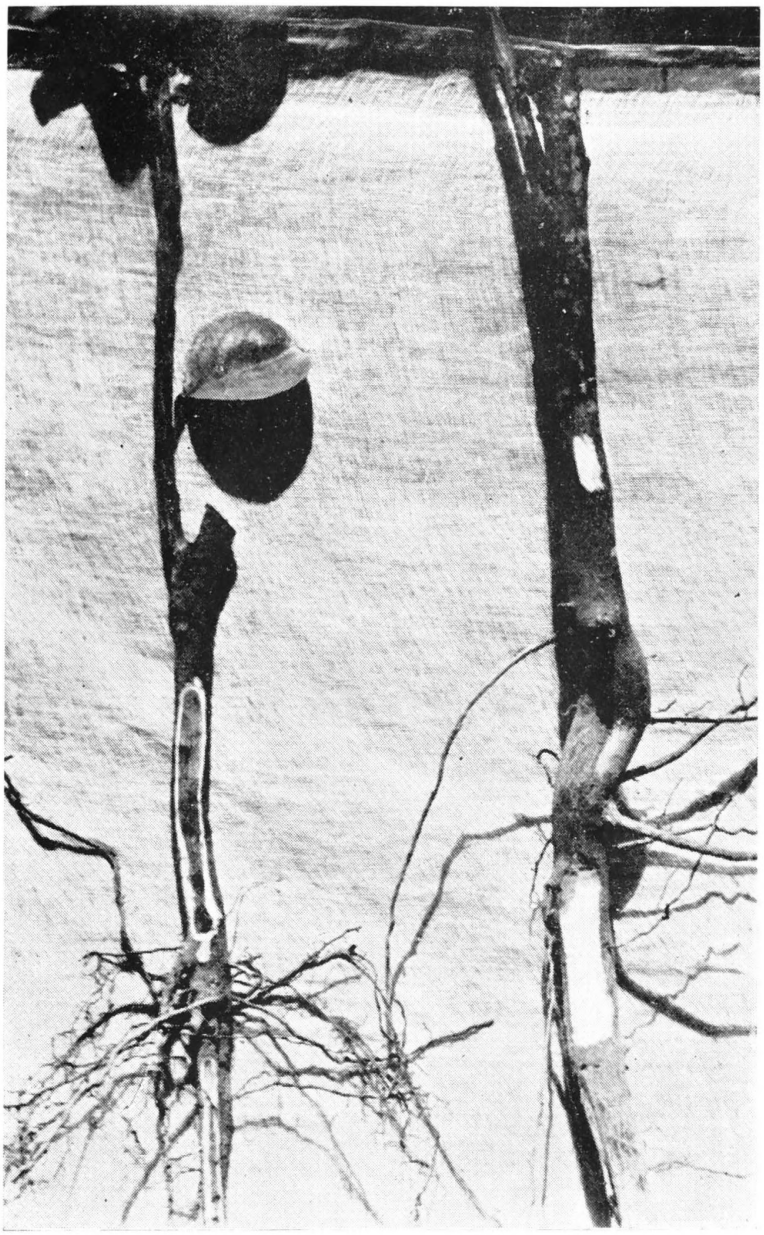

Plate 3.—Rough lemon stock budded to Marsh Seedless grapefruit on left shows presence of starch in root and stem portion below bud union when treated with iodine, but sour orange stock budded to same variety of grapefruit is devoid of starch.

APPENDIX I

Citrus Stock-Scion Trial—Moneragala

Analysis of Variance of Stock Girth Measurements

	DF	SS	Variance	F	1 per cent. point
Blocks	3	25·89	8·63	5·20	4·87
Treatment	7	75·02	10·72	6·46	3·65
Error	21	34·96	1·66		
Total	31	135·87			

Significant difference = ·91 inches

Analysis of Variance of Scion Girth Measurements

	DF	SS	Variance	F	1 per cent. point
Blocks	3	19·48	6·49	4·08	4·87
Treatment	7	53·99	7·71	4·85	3·65
Error	21	33·32	1·59		
Total	31	106·79			

Significant difference = ·89 inches

APPENDIX II

Citrus Stock-Scion Trial—Peradeniya

Analysis of Variance of Stock Diameter Measurements

	DF	SS	Variance	F	1 per cent. point
Blocks	5	·59	·118	·118	—
Treatment	3	68·33	22·78	22·78	5·42
Error	15	15·02	1·00		
Total	23	83·94			

Significant difference = ·85 cm.

Analysis of Variance of Scion Diameter Measurements

	DF	SS	Variance	F	1 per cent. point
Blocks	5	1·66	·332	·163	—
Treatment	3	34·52	11·51	5·64	5·42
Error	15	30·64	2·04		
Total	23	66·82			

Significant difference = 1·21 cm.