VIRUSLIKE DISEASES OF CITRUS

Abnormal Bud Union Between Some Sweet Oranges and Rough Lemon Rootstock: Evidence of Cause by a Transmissible Pathogen

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The abnormal union that some sweet oranges make with Rough lemon rootstock is characterized by a pitted ring in the trunk wood along the line of the union. A corresponding toothed projection from the inner face of the bark fits into the pitted ring (fig. 1A). In mild cases the abnormality is purely internal and cannot be detected on the surface. In severe cases, much disruption in the outer layers of bark results in a prominent, corky collar of eruptive bark encircling the trunk (fig. 1B). In intermediate cases the disruption of bark may be partial, with external cracks at some places but not completely around the trunk. In the projections and in the ridge of tissue carrying the projections are what appear to be zones of dark-colored, gum-impregnated tissue. They may be seen either by cutting longitudinally through the bark or by paring away the bark from the surface (fig. 4B). At points where external cracks occur, the dark, gum-impregnated tissue lies just below the surface, but where the surface is normal the discolored tissue is deeper. Functional phloem at the faulty union is very thin.

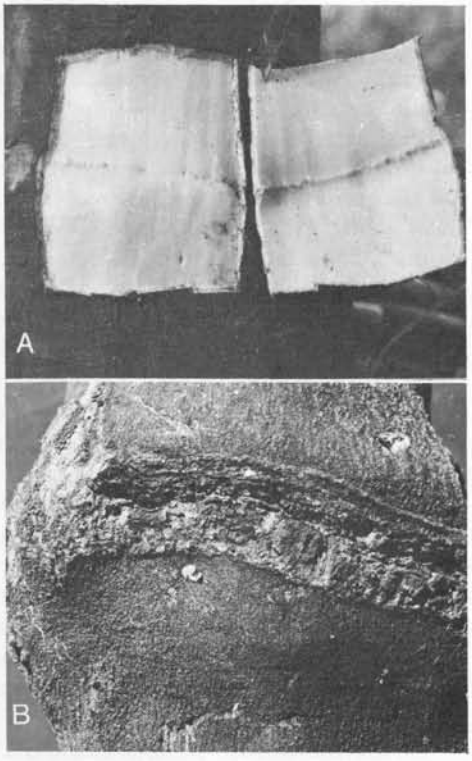

Fig. 1. Abnormal unions between sweet orange and Rough lemon. *A*, section of bark reversed: internal symptoms (old-line Washington navel scion). *B*, external fissure of eruptive bark (old-line Shamouti scion).

The disorder is not general for sweet oranges on Rough lemon stocks, but is confined to trees of some varieties and particularly to the clonal progeny of some old lines. Best examples are found among mid-season oranges, particularly some from Mediterranean countries, such as Blood, Shamouti, Jaffa, and Malta Egg. The faulty union between these varieties and Rough lemon is usually severe, and accompanied by the external fissure or corky collar.

The disorder is bud-propagated; parent trees that show it pass it on to their vegetative progeny. But an abnormal union develops only when the progeny trees are on Rough lemon.

Many countries have recorded this

disorder (*2, 3, 4, 5, 6, 7, 8, 9, 11*). Its cause has not been determined, but an unidentified virus has been suggested (*5*). Bridges and Youtsey (*1*), after extensive indexing of commercial citrus trees, concluded that the disorder was not correlated with the presence of exocortis, xyloporosis (cachexia), tristeza, or vein enation. Progeny trees of Hamlin, Valencia, and Pineapple that developed the disorder were invariably from parents similarly affected. On the other hand, all of 130 progeny trees from six nucellar clones of the same three varieties united normally with Rough lemon. These results suggest that an unidentified virus or a genetic factor not present in all clones of Hamlin, Valencia, and Pineapple may be responsible for the disorder. Bridges and Youtsey also noted differences in the severity of the disorder varying from very slight to very severe.

This paper records the occurrence of the disorder in commercially grown sweet oranges in South Africa, where the Rough lemon is still the main rootstock. It also presents evidence that the faulty union is caused by a transmissible pathogen.

BUD-UNION DISORDER IN COMMERCIALLY GROWN CITRUS IN SOUTH AFRICA

The two most widely grown varieties of sweet orange in South Africa are the Valencia and Washington navel. The unions of most old-line Valencias on Rough lemon are normal (fig. 2). A few exceptions, however, were found in an orchard in the Eastern Transvaal. The affected trees were 30 years old and showed a prominent external collar in addition to an internal ring in the wood (*6*). On the other hand, the unions of most old-line Washington navels on Rough lemon are abnormal, but the internal symptoms can be seen only by removing a strip of bark from the trunk. In old trees, however, external cracks often develop in the bark along the line of the union. Palmer navel, which is now being grown fairly extensively in South Africa, seems to make a normal union with the Rough lemon. Palmer navel is from a seedling tree of the Washington Navel, discovered on a farm in the Eastern Cape. This line is now tending to replace the old-line Washington navel because of better performance.

Fig. 2. Normal union of Valencia (old line) on Rough lemon.

Trees propagated on Rough lemon, at the Buffelspoort Experiment Station, from scion material collected in different districts of the Transvaal, confirm that most old-line Valencias make a normal union with Rough lemon, whereas most old-line navels make a faulty union.

Of the midseason oranges, those that make conspicuous faulty unions with Rough lemon are Tomango, Ruby, Shamouti, Jaffa, Hall's Midseason, and Letaba Early. These varieties all show a prominent fissure on the outside of

the trunk. Premier, Mid-Knight and Mediterranean Sweet, three other midseasons, showed well-defined internal symptoms similar to those of the Washington navel. Midseasons that usually make normal unions are Hamlin, Clanor, and Cape Seedling.

No experimental work has been done in South Africa to determine the extent to which trees are harmed by abnormal unions. One difficulty is that, hitherto, no scion material has been available that can make a normal union with Rough lemon and provide a basis for comparison. Affected trees mostly appear to grow satisfactorily, although they tend to be on the smaller side. Nevertheless, they crop well, possibly a response to the girdling effect of the faulty union. As a control, Marloth (7) recommended the use of either sweet orange or Empress mandarin as a rootstock for midseason oranges in South Africa.

TRANSMISSION EXPERIMENTS

In 1960, experiments were started at the Buffelspoort Experiment Station to investigate the transmissibility of the bud-union disorder. Trees were propagated on standard Rough lemon by the usual method of top-working scion buds to stock seedlings. The unions were examined by removing from the trunks sections of bark (3 to 4 × 6 cm) across the union, and observing the surfaces of the wood and bark. This was sufficient when the disorder was well defined, but in mild cases, especially when the internal ring was shallow and did not completely encircle the wood, it was sometimes necessary to remove a second or third strip of bark. No precautions were taken to control insects in the orchard except to prevent severe infestation by scale insects.

Table 1 shows the behavior of progeny trees propagated from affected parents. Some of the parents used were from the variety collection at the Citrus Research Institute, Nelspruit, and some from commercial orchards. All the progeny trees developed abnormal unions similar to those of the parents. This is in accordance with what happens in commercial orchards when affected clonal lines of sweet orange are propagated on Rough lemon.

Table 2 gives the results of inoculating young test trees on Rough lemon stock with buds from trees with abnormal unions. The scions used to propagate the trees were some old lines known to make a normal union with Rough lemon, and four seedling scions.

TABLE 1
PROPAGATION OF SWEET ORANGES ON ROUGH LEMON FROM PARENT TREES SHOWING ABNORMAL UNION ON ROUGH LEMON

Parent tree variety and condition	Progeny on Rough lemon	
	Total no.	No. with abnormal union
Marked internal and external symptoms:		
Addorosa	4	4
Blood	2	2
Hall's Midseason	4	4
Jaffa	4	4
Letaba Early	3	3
Maltese Blood	1	1
Shamouti	8	8
Shamouti sour orange hybrid*	3	3
Tomango	2	2
Valencia†	2	2
Milder external symptoms; marked internal symptoms:		
Vicidea	2	2
Premier	1	1
Washington navel tree No. 1	1	1
Washington navel tree No. 2	8	8

* An importation from Riverside, California: no evidence of any sour orange characters, probably pure Shamouti.

† Old-line Valencia with abnormal union is exceptional.

TABLE 2
TRANSMISSION OF THE CAUSAL AGENT OF BUD UNION DISORDER BY BUD GRAFTS

Test trees: sweet orange scions on Rough lemon stock	Trees inoculated from trees with abnormal unions*		Untreated trees	
	Total no.	No. positive	Total no.	No. positive
Seedling lines:				
Malta Egg	6	6	2	0
Pineapple	5	3	2	0
Valencia	6	5	3	0
Washington navel	7	5	3	0
Total	24	19	10	0
Old lines:				
Baths	2	0	2	0
Eloff	2	0	2	0
Moss	2	1	1	0
Rico	2	0	1	0
Pine	1	1	1	0
Hamlin	2	0	2	0
Pretoria navel	2	1	1	0
Total	13	3	10	0

* Sources of inoculum used: Maltese Blood, Midseason, Letaba Early, and Washington navel.

Initially the behavior of the seedling scions on Rough lemons was not known, but the scions of untreated trees subsequently united normally with the Rough lemon. After 10 years, 19 of 24 trees with the seedling scions, and three

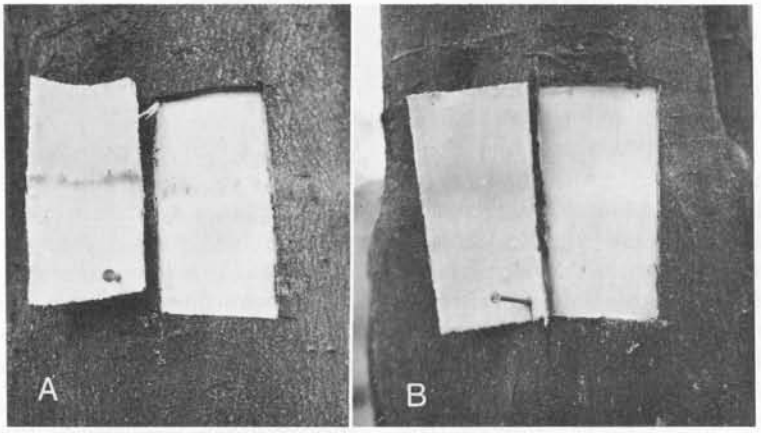

Fig. 3. Malta Egg seedling scion on Rough lemon. *A*, graft-inoculated from old-line Letaba Early orange: abnormal union. *B*, untreated control: normal union.

of 13 with old-line scions developed abnormal unions following inoculation (fig. 3A). All 20 untreated controls have normal unions (fig. 3B). Positive trees show a pitted ring in the wood and a corresponding toothed projection from the inner face of the bark. A few trees have slight external cracks in the bark The reaction was slight in some trees, especially in the Pineapples. It was better defined in Malta Egg, Pine, and Pretoria navel. The severity of the reaction was apparently much the same whether the inoculum source was a severe form of the disorder or a milder form. All the trees in the experiment, both inoculated and controls, were infected with tristeza virus, and all showed stem pitting in their trunks.

The results of another experiment confirm that the abnormal bud union between sweet orange and Rough lemon can be induced by inoculating normal trees with grafts from affected ones. This experiment was started by inoculating Rough lemon seedlings. Later, the Rough lemons were topworked to a seedling line of Valencia, and planted in the open at Buffelspoort. After nine years (table 3), all the trees inoculated from affected sources developed abnormal unions. Those inoculated with tissue from normal sources developed normal unions. Exceptions are trees inoculated from an apparently normal old-line Hamlin. All 15 untreated controls have normal unions (fig. 4C). The two trees inoculated from old-line Verna orange showed the most pronounced reaction, including external cracks in the bark (fig. 4A). Unions of some other inoculated trees were still only very mildly affected, and showed slight pitting only in some sections of the union.

In another experiment composite trees of Valencia and Rough lemon were inoculated with grafts from the same old-line Verna orange. Three of the trees had Valencia seedling scions on Rough lemon stocks, and two had Rough lemon seedling scions on seed-

TABLE 3

INOCULATION OF VALENCIA TREES* ON ROUGH LEMON BY GRAFTING FROM TREES WITH EITHER NORMAL OR ABNORMAL UNION ON ROUGH LEMON

Inoculum source	Total trees inoculated	Type of union	
		Normal	Abnormal
Sweet oranges, abnormal union:			
Verna	2	0	2
Washington navels	9	0	9
Tomango	3	0	3
Shamouti	2	0	2
Sweet oranges, normal union:			
Valencias	6	6	0
Olinda Valencia	3	3	0
Pera	3	3	0
Hamlin	4	0	4
Pretoria navel	3	3	0
Tangerine, grapefruit† and Eureka lemon	9	9	0
Untreated controls	15	15	0

* All trees with same Valencia seedling scion on Rough lemon.

† The effect of viruses present in these trees on union between sweet orange and Rough lemon was unknown.

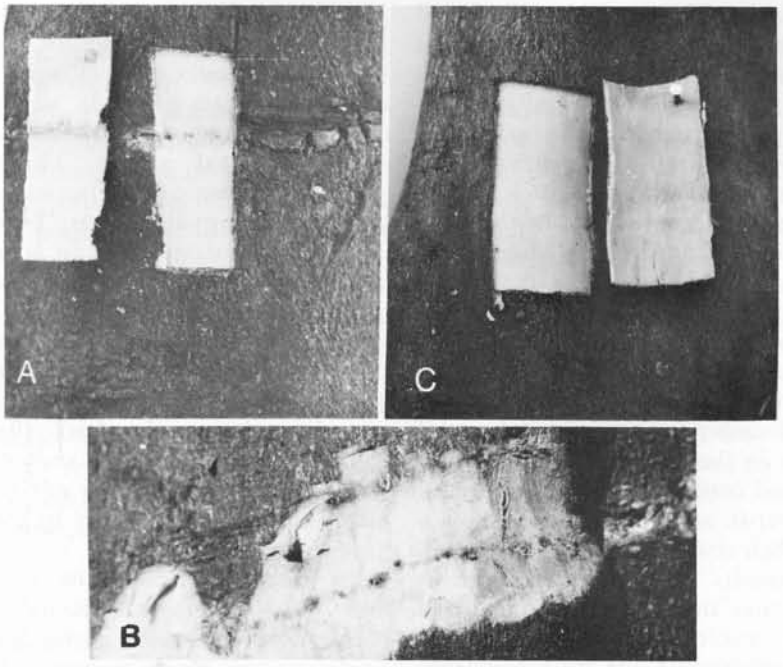

Fig. 4. Valencia seedling scion on Rough lemon. *A*, graft inoculated from old-line Verna orange: internal symptoms and external fissure. *B*, same tree with bark pared away at union to show internal discolored ring. *C*, untreated control: normal union.

TABLE 4

BEHAVIOR OF OLD-LINE SWEET ORANGES AND THEIR SEEDLING PROGENY ON ROUGH LEMON AND EMPRESS MANDARIN STOCKS

Scions	Rootstock	Total trees	Type of union	
			Normal	Abnormal
Shamouti*				
Old-line	Rough lemon	6	0	6
	Empress mandarin	3	3	0
Seedling No. 1	Rough lemon	5	5	0
	Empress mandarin	3	3	0
Seedling No. 2	Rough lemon	6	5	1
	Empress mandarin	3	3	0
Seedling No. 3	Rough lemon	6	2	4
	Empress mandarin	3	3	0
Letaba Early†				
Old-line	Rough lemon	3	0	3
Seedling No. 1	Rough lemon	1	1	0
Seedling No. 2	Rough lemon	1	1	0
Seedling No. 3	Rough lemon	1	1	0

* The three parent seedlings of Shamouti were raised at Ingonini Estates, Swaziland.
† Letaba Early seedlings were raised at Buffelspoort.

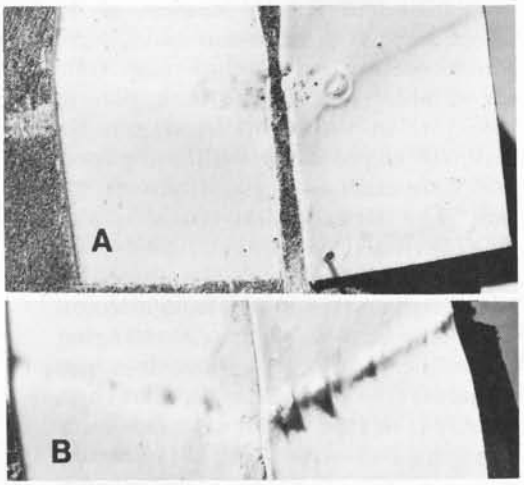

Fig. 5. Untreated Shamouti seedling scions on Rough lemon. *A*, seedling No. 1 with normal union. *B*, seedling No. 3 with abnormal union.

ling Valencia stocks. All these trees, after nine years, showed internal symptoms at the bud union.

Another experiment was designed in which we studied the behavior on Rough lemon stocks of uninoculated seedling scions raised from parents that make a severe bud-union disorder with Rough lemon. Table 4 records the behavior on Rough lemon of two old-line sweet oranges (Shamouti and Letaba Early), and some seedling lines raised from them, and the behavior of Shamouti lines on Empress mandarin stock. The trees are now 10 years old. All the old-line progeny on Rough lemon developed severe abnormal unions. This is characteristic of the clonal progeny of the two varieties in South Africa. Of the progeny of the seedling lines, all the trees, except one of six of Shamouti seedling No. 2, and four of six of seedling No. 3, developed normal unions (fig. 5A). The exceptions (fig. 5B) developed an internal pitted ring, and in one case, some external cracks. All Shamouti lines on Empress mandarin stocks developed normal unions.

The vigorous and larger Shamouti trees were the ones with the seedling scions. This applied to trees on both Rough lemon and Empress mandarin. The average height of the trees with seedling scions was 335 cm as compared with 243 cm for trees with old-line scions.

DISCUSSION AND CONCLUSIONS

Results of transmission experiments provide evidence that a transmissible pathogen is the cause of the abnormal union between some sweet oranges and Rough lemon rootstock. Healthy test trees inoculated by grafts from affected trees consistently developed the characteristic symptoms at the unions. Uninoculated trees propagated from the same parent scions made normal unions with Rough lemon.

Some progeny trees of two untreated seedling lines of Shamouti orange made abnormal unions with Rough lemon. The progeny of a third seedling made normal unions. The history of these seedling scions, however, is not known to the writer. Such exceptions may indicate that the pathogen is sometimes transmitted through the seed. But there is also the possibility that some seedlings of a variety like the Shamouti possess an inherent incompatibility for the Rough lemon. The writer's experience has been mainly with seedling lines of Valencia and Washington navel. All healthy seedling scions of these two varieties have proved compatible with Rough lemon.

The pathogen causing the abnormal union has not yet been identified. Reliable evidence suggests it is not caused by exocortis, xyloporosis, psorosis, tristeza, or vein enation (*1*). One virus so far not excluded is cristacortis (*10*), although at present there is no direct evidence for suspecting it. Pitting has not

been observed in sweet orange scions making an abnormal union with Rough lemon stocks in South Africa. Many of the old-line sweet oranges that make abnormal unions with Rough lemon are of Mediterranean origin. Therefore, the pathogen responsible for the disorder must be present in many of the sweet oranges grown in countries bordering the Mediterranean. Its presence, however, would largely escape notice, because the Rough lemon is not used to any extent as a stock in those countries.

The symptoms of the bud-union disorder between sweet orange and Rough lemon are very similar to those apparently caused by genetic incompatibility, for example, the ones between Triumph grapefruit and Rough lemon and between some lines of lemon and the trifoliate orange. All produce pegs from the cambial face of the bark that fit into pits in the wood. And gumlike material is produced within the pegs and sometimes in the bottoms of the pits. The latter characteristic is also true of cristacortis.

The problem of a faulty union between sweet oranges and Rough lemon cannot be solved by merely changing to another stock, since this does not eliminate the causal agent. The best remedy is to start afresh with new seedling lines. New scion materials are available, and certain of these are now being grown commercially.

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