Bud-Union Crease of Calamondin—a Non-Infectious Disorder

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WHEN CERTAIN CITRUS varieties are grown on calamondin [*Citrus reticulata* var. *austera* x *Fortunella* sp.] rootstock, a disorder called bud-union crease occurs. Of course, bud-union disorders in citrus may be caused either by viruses or tissue incompatibilities. This paper reports recent research which suggests that bud-union crease results from tissue incompatibilities.

History and Description

Bud-union crease was originally reported affecting trees on calamondin rootstock in Texas (3, 4). The disorder also occurs in California (8), Florida, and Brazil (5, 6). Other instances of failure of citrus on calamondin rootstock have been reported (4).

The first symptom of bud-union crease on calamondin rootstock appears as a brown, gum-impregnated zone, 2 to 5 mm wide, on the cambial face of the bark at the bud-union. The outer bark later splits along

the bud-union, leaving a scarred depression. The tops of affected trees may exhibit poor growth and chlorosis symptoms resembling those occurring on girdled trees. Sprouts grow vigorously from below the bud-union, and if the top is removed at the bud-union, these sprouts will form a normal calamondin tree.

In Texas, Olson (4) regarded the disorder as an incompatibility associated with some kumquat and kumquat-hybrid tops or rootstocks in combination with certain kinds of citrus. In California, Weathers and Calavan (8) considered bud-union crease a bud-perpetuated, non-transmissible disorder. They found 6 different rootstock varieties which produced bud-union crease when propagated with old-budline calamondin tops, but which grew normally with nucellar calamondin tops. However, when nucellar calamondins on the same rootstocks were inoculated with old-budline calamondin tissue, the trees remained free of bud-union crease.

Weathers (personal communication, 1965) later top worked old-budline calamondin onto the nucellar calamondins on these same 6 rootstocks so that old-budline calamondin formed the tops and the nucellar calamondin formed an interstock. These trees developed bud-union crease at the lower union, between the nucellar calamondin interstock and the rootstock. Evidently something was translocated from the old-budline calamondin across the nucellar calamondin interstock, because nucellar calamondin on the same 6 rootstocks failed to show bud-union crease when they were 8 years old. Weathers suggested that his old-budline and nucellar calamondins were different, even though the nucellar selection was a seedling from the old-budline tree used in the experiment.

At Weslaco, Texas, 8 trees of old-budline calamondin were propagated on Taiwanica (*C. aurantium* L. hyb.) rootstock (Bailey Sleeth, unpublished data). Seven were 10 feet high in 1966, and were free of bud-union crease. The eighth tree was only 3 feet high, chlorotic, and had bud-union crease. Probably the tree with bud-union crease had a seedling rootstock genetically different from the others. Off-type seedlings of Taiwanica are common.

At Indio, California, nucellar calamondin trees on Carrizo and Troyer citranges grew vigorously (J. R. Furr, unpublished data) and 7-year-old trees were free of bud-union crease. However, nucellar and old-budline kumquats (*Fortunella* sp.) on the same rootstocks died from bud-union crease a few years after budding. These results suggest that the compatibility reactions of kumquat and nucellar calamondin are not necessarily identical.

Materials and Methods

At Monte Alto, Texas, calamondin seedlings were budded with the scion and interstock varieties listed in Tables 1, 2, and 3. Except for certain old budlines, the scion varieties were considered free of exocortis, xyloporosis, psorosis, and tristeza viruses on the basis of seedling origin and/or indexing trials. However, Meyer lemon [*C. limon* (L.) Burm. f. hyb.] carried tatter-leaf virus; Redblush grapefruit (*C. paradisi* Macf.) carried exocortis and xyloporosis viruses; and Clementine mandarin (*C. reticulata* Blanco) and Temple (mandarin hybrid) carried exocortis

TABLE 1. VARIETIES COMPATIBLE WITH CALAMONDIN ROOTSTOCK AND FREE OF BUD-UNION CREASE FOR MORE THAN 30 MONTHS WHEN GROWN AT MONTE ALTO, TEXAS

Kumquats (*Fortunella*)	Mandarins
Marumi (N)[a]	Cleopatra (N)
Meiwa (N)	Changsha (N)
Nagami (OL)[a]	Dancy (N)
Obovata (S)[a]	Kansu (N)
Hongkong (S)	Kunembo (N)
Lemons	Satsuma (N)
Lemonquat (N)	Satsuma hybrid (S)
Meyer lemon (OL)	Suen Kat (N)
Rough lemon (N)	Sun Chu Shu Kat (N)
Sour orange hybrid	Szincal No. 9 (S)
Taiwanica (N)	C52-76-9 (Umatilla x Honey)
Limes	C54-2-1 (Clementine x Satsuma)
Eustis limequat (OL)	Miscellaneous
Eustis limequat (S)	*C. tachibana* (Mak.) Tan (S)
Mexican lime (N)	*Poncirus trifoliata*
Rangpur mandarin lime (N)	
Trifoliate orange hybrids	
Glen citrangedin (S)	
Thomasville citrangequat (N)	
Morton citrange (N)	

a. N = nucellar, OL = old budline, S = open-pollinated seedlings.

virus. The calamondin seedlings were budded in 1958, 1961, and 1963. After an interval of at least 30 months, the budded trees were examined for symptoms of bud-union crease by cutting a strip of bark approximately 1 in. long and ¼ in. wide from the trunk across the bud-union. A zone of brown discoloration, 2 to 5 mm wide on the inner bark surface at the bud-union, was considered evidence of bud-union crease.

Trials with old-budline calamondin and kumquat tops were conducted at the University of California at Los Angeles at irregular intervals during the same period (Table 3). The virus status of these trees is not

known, but the trees were grown in an area where vein-enation virus was common and spreading.

Results

Selections that caused bud-union crease with calamondin rootstock were certain mandarins, grapefruit, Ichang pummelo (*C. ichangensis* Swing. hyb.), sweet orange, Eureka and Lisbon lemons, sour orange (*C. aurantium* L.), and certain hybrids of trifoliate orange [*Poncirus trifoliata* (L.) Raf.] (Table 1). Most of the selections tested were of recent nucellar, hybrid, or open-pollinated-seedling origin.

Selections found compatible with calamondin rootstock were certain mandarins and lemons, Mexican lime [*C. aurantifolia* (Christm.) Swing.], Rangpur mandarin lime, and kumquat (*Fortunella*) species and hybrids (Table 2).

TABLE 2. VARIETIES INCOMPATIBLE WITH CALAMONDIN ROOTSTOCK AND SHOWING BUD-UNION CREASE WITHIN 30 MONTHS WHEN GROWN AT MONTE ALTO, TEXAS

C. ichangensis Swing. hybrid	Mandarins
Ichang pummelo (S)[a]	Clementine (OL)
Grapefruit	Fortune (Clementine x Dancy)
Redblush (O)[a]	Honey (OL)
Redblush (N)[a]	Kara (King mandarin x Satsuma) (N)
Lemons	Lee (Clementine x Orlando)
Eureka (N)	Long Huang Kat (N)
Lisbon (N)	Murcott (N)
Sour orange	Ponkan (N)
Chinotto (N)	Richard's Special (S)
Sweet oranges	Tim Kat (N)
Jaffa (N)	Temple "orange" (OL)
Moro blood (S)	De Ba Ahmed (S)
Shamouti (OL)	C54-1-4 (Clementine x Silverhill Satsuma)
Shamouti (N)	C54-1-5 (Clementine x Silverhill Satsuma)
Valencia (OL)	
Valencia (N)	
Trifoliate orange hybrids	
Troyer citrange (N)	
C61-220 (Cleopatra x Troyer hybrid) (S)	
C53-30-1 (Citradia[b] x unknown)	

a. S = open-pollinated seedling; OL = old budline; N = nucellar.
b. Citradia = sour orange x *P. trifoliata.*

When old-budline calamondin was grown on sweet orange [*C. sinensis* (L.) Osb.] rootstock in California, or a nucellar grapefruit top was grown on calamondin rootstock in Texas, bud-union crease developed. However, when Cleopatra mandarin or Rough lemon was used as an

interstock between incompatible components, bud-union crease failed to develop within a three-year period (Table 3 and Fig. 1).

Although Swingle (7) considered calamondin to be a mandarin-kumquat hybrid, the incompatibility reactions of the kumquats were not identical with those of calamondin. In California, old-budline kumquat trees grew well on calamondin and on sweet orange rootstock and made excellent bud-unions. However, old-budline calamondin tops, with kumquat interstock, on sweet orange rootstock developed mild bud-union crease between the sweet orange and kumquat. Also, calamondin grew well on Rough lemon whereas kumquat did not. Old-budline kumquat trees on Rough lemon rootstock often showed a swelling like a collar at the bud-union. In Florida, this disorder, podagra, was neither infectious nor transmissible, according to Knorr (1).

TABLE 3. RELATION OF INTERSTOCKS TO COMPATIBILITY OF CALAMONDIN UNIONS BASED ON OCCURRENCE OF BUD-UNION CREASE 3 OR MORE YEARS AFTER BUDDING AT MONTE ALTO, TEXAS, OR LOS ANGELES, CALIFORNIA

Scion-rootstock combination	Interstock	No. plants in test	No. plants with bud-union crease
Redblush grapefruit (N)[a] on calamondin rootstock	none	5	5
Cleopatra mandarin (N) on calamondin rootstock	none	5	0
Redblush grapefruit (N) on calamondin rootstock	Cleopatra mandarin (N)	3	0
Calamondin (OL)[a] on sweet orange rootstock	none	3	3
Calamondin (OL) on Rough lemon rootstock	none	5	0
Calamondin (OL) on sweet orange rootstock	Rough lemon	5	0[b]

a. N = nucellar, OL = old budline.

b. Severe brown-colored grooving occurred above bud-union; both bud-unions were mechanically strong, unlike bud-union crease. See Figure 1,D,E.

Discussion and Conclusions

Evidence that incompatibility between the tissues of certain citrus varieties and calamondin causes bud-union crease is as follows:

1) All selections (nucellar, seedlings, and old budline) of sweet orange and grapefruit, eight in all, produced bud-union crease on calamondin. There were no non-reacting sources such as might be encountered in virus diseases when some sources did not contain the virus.

2) Bud-union crease occurred between sweet orange and calamondin irrespective of which was the rootstock or the top.

3) No bud-union crease occurred within three years after grafting, if compatible interstocks were used as a bridge between incompatible combinations.

4) Bud-union crease failed to develop with old-budline or nucellar lines of kumquat, kumquat-hybrid, and calamondin-hybrid tops on calamondin rootstock.

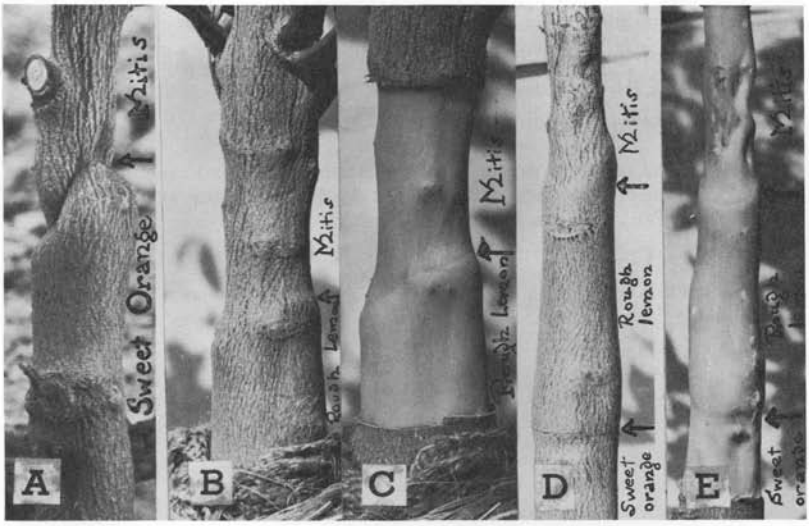

FIGURE 1. *Old-budline calamondin* (C. mitis *in these illustrations) on various rootstocks and interstocks at the University of California at Los Angeles. Bud-unions are indicated by arrows. A. Bud-union crease at juncture of calamondin and sweet orange. B. and C. Compatibility of calamondin and Rough lemon. D. and E. Compatibility of calamondin and sweet orange when Rough lemon interstock is inserted between the incompatible components. The cause of the severe grooving in the calamondin top, a short distance above the upper bud-union, is unknown.*

5) Since most citrus viruses are not seed transmitted, occurrence of bud-union crease with an old-budline selection, as opposed to a nucellar selection, would suggest a virus as the causal agent. However, both nucellar and old-budline selections of certain varieties caused bud-union crease of plants on calamondin rootstock in Texas.

6) The cause of bud-union crease was not transmissible from affected plants to normal ones (8).

7) Bud-union crease did not spread in the field.

8) The symptoms of bud-union crease in citrus resemble those of localized incompatibilities in other kinds of fruit trees (2).

CONCLUSION.—Bud-union crease of certain varieties of citrus on calamondin rootstocks appears to result from tissue incompatibilities.

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