I. REICHERT, A. BENTAL, and O. GINSBURG

Bud-Union Constriction Disorder of Grapefruit on Sour Orange in Israel

A BUD-UNION disorder affecting Marsh seedless grapefruit (*Citrus paradisi* Macf.) on local sour orange (*C. aurantium* L.) rootstock was first found in Israel in one grove in the Esdraelon Valley in 1959. The symptoms and spread of this disorder and tests made for determination of its cause are described here.

Methods

The affected plot, belonging to Ein Harod settlement, formed part of a 30-year-old plantation on heavy soil on the slopes of Mt. Gilboa. The plot was located on the lower part of the slope where the soil accumulated moisture. The trees in plots higher on the slope did not show any marked decline symptoms. For the purpose of the survey, 15 rows of trees, representing one-third of the rows in the affected plot, were chosen at random. Each row consisted of 20 trees, for a total of 300 trees.

Each individual tree was examined for its general state of health, and a piece of bark was stripped off across the bud-union to detect any pathological symptoms in the cambium region of stock and scion.

For anatomical examinations, bark samples were taken from 10 affected and 5 normal trees. Sampling, sectioning, and staining were carried out by Schneider's method (24), as described elsewhere (20).

To test the trees for the presence of tristeza virus, budwood samples were grafted on Mexican lime [*C. aurantifolia* (Christm.) Swing.] seedlings in an insect-proof screenhouse.

Description and Observations

Affected trees had reduced growth, small leaves, and various stages of defoliation and dieback of twigs and branches; in the most severe cases, the trees eventually died.

Many of the trees had a slight swelling of the scion at the bud-union and, upon removal of a piece of the bark across the bud-union, were seen to have a 1-4 mm deep constriction in the wood around the line of union (Fig. 1,A) with a corresponding toothed ridge protruding from the inner face of the bark (Fig. 1,B). No discoloration or gum pockets could be

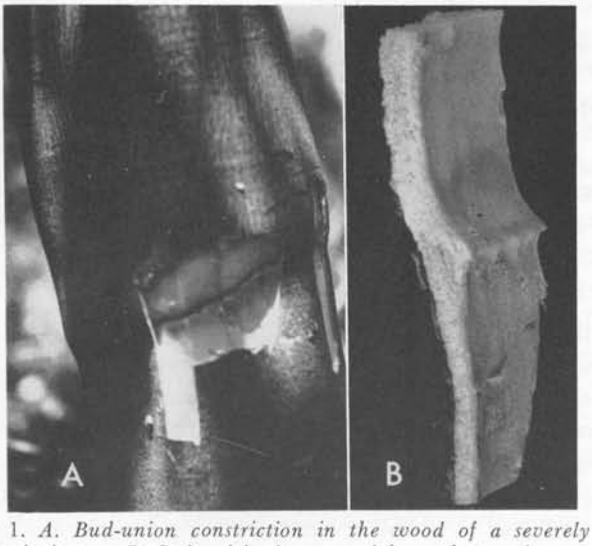

FIGURE 1. *A. Bud-union constriction in the wood of a severely declining Marsh grapefruit tree. B. Strip of bark removed from the trunk across the bud-union showing the toothed ridge at the line of union and inverse pitting (pinholing) in the sour orange rootstock.*

noticed in the trees examined. The constriction did not always encompass the entire circumference of the trunk.

In many trees with such constriction of the bud-union there was inverse pitting (honeycombing, pinholing) in the sour orange rootstock, beginning at the union, descending in a dense form for 10-30 mm, and becoming scarce or disappearing at a lower level. Xyloporosis pitting was observed in the wood of some trees, mostly in their rootstocks.

First symptoms of the disorder were observed on two trees in 1959. Observations made in 1961 revealed 34 trees with decline. During the following year, the number of declining trees increased greatly, and a detailed survey was carried out in spring, 1963. The results of the survey are summarized in Table 1. Mortality in the entire plot amounted to 15 per cent.

TABLE 1. OBSERVATIONS ON 300 MARSH SEEDLESS GRAPEFRUIT TREES ON SOUR ORANGE AT EIN HAROD

Group	Appearance	Number of trees examined	Percentage of trees (per group) showing:				
			Constriction	Swelling	Pitting in wood[a]	Inverse pitting[b]	Psorosis
A	Normal	81	16	23.4	2.4	—	3.7
B	Slightly declining	60	26.6	31.6	1.6	—	6.6
C	Moderately declining	82	25.6	35.3	13.5	3.6	24.6
D	Severely declining	77	65	68.8	3.9	40.2	22
	Total	300	33.3	40	5.7	11.3	14.6

[a]Either in stock or scion.
[b]In the sour orange stock.

From the table, it can be seen that there was a high degree of correlation between bud-union constriction and degree of decline, between swelling of the scion at the bud-union and degree of decline, and between inverse pitting and degree of decline. There was no correlation of xyloporotic pitting of the wood and degree of decline.

Psorosis of the bark-scaling type was found in trees of all groups. Trees in the moderately and severely declining groups were more often affected by psorosis than those in the other groups. To test for a relationship between psorosis and the bud-union constriction disorder, 40 psorosis-affected trees in an adjacent plot were examined after stripping off a piece of bark across the bud-union. None of the trees examined showed the constriction.

Starch Tests

Iodine (IKI) solution applied to a cut made into the wood across the bud-union of ten trees in each group showed starch accumulation to be equal in stock and scion of all trees graded as normal, or slightly or moderately declining. Of the severely declining trees only four, all of them almost dead, showed starch depletion below the union. All these trees had very pronounced bud-union constriction. Our starch tests indicate a difference between the grapefruit disorder and that of Eureka lemon [*C. limon* (L.) Burm. f.] on Troyer citrange [*C. sinensis* Osbeck x *Poncirus trifoliata* (L.) Raf.] described by Weathers *et al.* (25), who reported starch depletion as a symptom.

Tristeza Transmission Tests

The declining state of the affected trees, their retarded growth, swelling of the scion, and especially the appearance of inverse pitting in the sour orange rootstock strongly suggested the possibility of tristeza infection, and induced us to make transmission tests on Mexican lime seedlings.

Thirty graft inoculations carried out in three successive sets of tests failed to induce vein clearing in the leaves of the lime seedlings, thus indicating that the decline of the grapefruit trees was not caused by tristeza virus. Six months later, one-half of these seedlings were graft-inoculated with budwood from tristeza-infected trees; they developed typical vein-clearing symptoms, thus proving that absence of symptoms resulting from the previous inoculation was not due to insusceptibility of the lime seedlings.

Anatomical Examinations

Radial sections across the pegs of the ridge protruding from the bark revealed a considerable concentration of phloem fibers. These fibers and other phloem elements lose their regular vertical orientation and curve according to the shape of the peg (Fig. 2,A). The zone of functioning phloem within the pegs composing the ridge may be narrow, 150 microns or less as compared to 400-500 microns in normal trees, especially toward the point of the peg; or it may be absent altogether. In other cases, the pegs consist mostly of parenchymatous tissue, probably originating from ray cells and necrotic sieve tubes.

Examination of the bark sections taken from below the ridge, where inverse pitting occurred, revealed hyperplasia and lignification of the ray cells as well as sieve tube necrosis and hypertrophy of phloem parenchyma cells (Fig. 2,B).

Discussion

The type of bud-union abnormality described above is not new. It was first noticed on Shamouti sweet orange (*C. sinensis* Osbeck) on

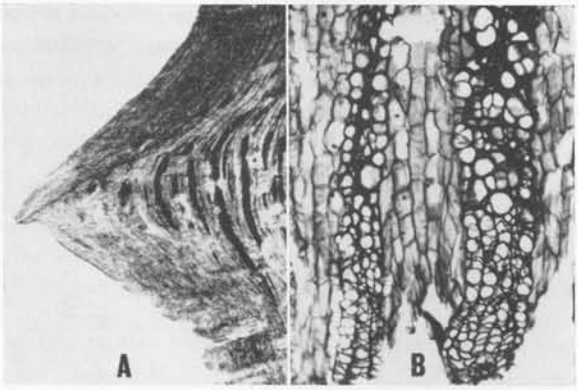

FIGURE 2. *A. Radial section of bark across the ridge showing concentration of phloem fibers and necrotic sieve tubes in the peg (x13). B. Cross section of sour orange bark just below the bud-union showing hyperplastic rays, necrosis of sieve tubes, and hypertrophy of parenchyma cells (x107).*

rough lemon (*C. jambhiri* Lushington) in Israel in 1931 (9, 13, 27) and later in Florida (2, 5), Brazil (4), South Africa (7, 8), Argentina (6), and Egypt (11). It was originally described as a corky fissure surrounding the tree at the place of union (9, 13, 27). Later a narrow constricted pitted groove in the wood at the union, with a corresponding toothed ridge projecting from the cambial face of the gum-impregnated bark, was also observed (2, 5, 8).

Similar bud-union abnormalities were reported from various citrus-growing countries on different scion-rootstock combinations (1, 4, 6, 8, 10, 12, 21, 25), particularly on the rootstocks of trifoliate orange and its hybrids, but never on grapefruit when grafted on sour orange.

The newly reported disorder on Marsh grapefruit trees growing on sour orange rootstock resembles the above-mentioned bud-union disorders, but differs from them by a less prominent swelling at the union, by lack of corky fissure or crease surrounding the union, and by absence of gum pockets or phloem discoloration in the bark.

Incompatibility (4, 5, 12, 25), in addition to viruses, has been suggested as possible cause of these abnormalities. Incompatibility may be ruled out (8) because the same varieties have been observed under identical conditions both with and without the abnormal symptoms. In the grapefruit grove in Israel, where the new disorder was found, most of the trees were normal.

Thus only a virus can be considered as the likely cause of the grapefruit disorder described here. Xyloporosis virus would be a plausible cause. This assumption is supported by the anatomical structure of the pegs composing the ridge protruding from the bark into the wood. The accumulation of phloem fibers within the tissue of such pegs or behind it is an anatomical feature described for xyloporosis as far back as 1934 by Reichert and Perlberger (14) and confirmed by Winocour (26). Additional support for this assumption may be found in the relatively frequent occurrence of xyloporosis pitting in the sour orange rootstock of declining trees, a phenomenon definitely unusual on the local sour orange (15).

The occurrence of inverse pitting on many trees affected by the new disorder does not conflict with the possibility that the causal agent may perhaps be xyloporosis; on the contrary, it may support this assumption. Elsewhere (15, 16, 18) we mentioned the coappearance of inverse pitting with xyloporosis. This was later reported also by McClean and Engelbrecht (8). Inverse pitting on sour orange rootstock is usually found on trees affected by tristeza (3, 17, 22) or by tristeza-like disorders (19, 20, 23), but in these cases it was never associated with bud-union constriction. The presence of inverse pitting on xyloporosis affected trees may perhaps be considered the result of their devitalisation caused by the virus. It cannot be ascribed to the more humid soil conditions in which the affected trees grew, because two trees suffering from root rot did not show any abnormal bud-union symptoms. The decline of grapefruit on sour orange in Israel may therefore be due to xyloporosis virus. This possibility is now being studied in inoculation experiments with budwood from affected grapefruit trees on various citrus varieties.

Literature Cited

1. Anonymous. 1955. 1955 Annual Report Citrus Field Research, Inc., Santa Barbara, California. 10 p. [As quoted by Olson (12).]
2. Childs, J. F. L., Grimm, G. R., Grant, T. J., Knorr, L. C., and Norman, G. 1955. The incidence of xyloporosis (cachexia) in certain Florida citrus varieties. Proc. Florida State Hort. Soc. 68: 77-82.
3. Cohen, M., and Knorr, L. C. 1954. Honeycombing—a macroscopic symptom of tristeza in Florida. Phytopathology 44: 485.
4. Grant, T. J., Moreira, S., and Costa, A. S. 1957. Observations on abnormal citrus rootstock reactions in Brazil. Plant Disease Reptr. 41: 743-748.
5. Grimm, G. R., Grant, T. J., and Childs, J. F. L. 1955. A bud-union abnormality of rough lemon rootstock with sweet orange scions. Plant Disease Reptr. 39: 810-811.
6. Fernández Valiela, M. V. 1961. Citrus virus diseases in Argentina, p. 231-237. *In* W. C. Price [ed.], Proc. 2nd Conf. Intern. Organization Citrus Virol. Univ. Florida Press, Gainesville.

7. MARLOTH, R. H. 1957. Rootstocks for Jaffa and Joppa oranges. J. Hort. Sci. 32: 162-171.
8. MCCLEAN, A. P. D., and ENGELBRECHT, A. H. P. 1958. Xyloporosis, cachexia, and abnormal bud-unions in South African citrus trees. S. African J. Agr. Sci. 1 (4): 389-413.
9. MENDEL, K. 1956. Rootstock-scion relationship in Shamouti trees on light soil. Ktavim 6: 35-60.
10. MOREIRA, S. 1938. Um interessante caso de desharmonia na enxertia de citrus. J. Agron. 1 (1): 57-61. [As quoted by Salibe (21).]
11. NOUR-ELDIN, F. 1959. Citrus virus disease research in Egypt, p. 219-227. *In* J. M. Wallace [ed.], Citrus Virus Diseases. Univ. Calif. Div. Agr. Sci., Berkeley.
12. OLSON, E. O. 1958. Bud-union crease, a citrus disorder associated with some kumquat-hybrid rootstocks and scions. J. Rio Grande Valley Hort. Soc. 12: 27-34.
13. OPPENHEIMER, H. J. 1940. The stock problem of the Shamouti orange. Hadar 13: 245-248.
14. REICHERT, I., and PERLBERGER, J. 1934. Xyloporosis—the new citrus disease. Hadar 7: 163-167, 172, 183-202.
15. REICHERT, I., YOFFE, I., and BENTAL, A. 1953. Shamouti orange on various rootstocks and its relation to xyloporosis. Palestine J. Bot. (Rehovot Ser.) 8: 163-184.
16. REICHERT, I., and WINOCOUR, E. 1956. Inverse pitting in xyloporosis and tristeza. Phytopathology 46: 527-529.
17. REICHERT, I., BENTAL, A., GINSBURG, O., and YOFFE, I. 1960. Tristeza disease in native commercial citrus trees in the Mediterranean. F.A.O. Plant Prot. Bull. 8: 43-45.
18. REICHERT, I., and BENTAL, A. 1961. On the problem of xyloporosis and cachexia diseases of mandarins. Plant Disease Reptr. 45: 355-361.
19. REICHERT, I., and GINSBURG, O. 1961. Observations on declining sour orange seedling trees in Spain. Plant Disease Reptr. 45: 945-948.
20. REICHERT, I., BENTAL, A., and GINSBURG, O. 1963. Valencia orange decline in Israel. Plant Disease Reptr. 47: 183-186.
21. SALIBE, A. A. 1961. Scion-rootstock incompatibilities in Brazil, p. 172-176. *In* W. C. Price [ed.], Proc. 2nd Conf. Intern. Organization Citrus Virol. Univ. Florida Press, Gainesville.
22. SCHNEIDER, H. 1954. Anatomy of bark of bud-union, trunk, and roots of quick-decline affected sweet orange trees on sour orange rootstock. Hilgardia 22: 567-581.
23. SCHNEIDER, H. 1957. Chronic decline, a tristeza-like bud-union disorder of orange trees. Phytopathology 47: 279-284.
24. SCHNEIDER, H. 1960. Sectioning and staining pathological phloem. Stain Technol. 35: 123-127.
25. WEATHERS, L. G., CALAVAN, E. C., WALLACE, J. M., and CHRISTIANSEN, D. W. 1955. A bud-union and rootstock disorder of Troyer citrange with Eureka lemon tops. Plant Disease Reptr. 39: 665- 669.
26. WINOCOUR, E. 1956. The anatomy and histology of healthy and xyloporosis affected Palestine sweet lime rootstocks budded to Shamouti sweet orange. Bull. Res. Counc. Israel, Vol. 5D: 125-142.
27. YEDIDYAH, S. 1937. Citrus growing (2d ed.). Tel Aviv. (Hebrew).