Effect of Various Concave-Gum Isolates on Mandarin and Sweet Orange Trees: Absence of Correlation Between Reduction of Growth and Severity of Symptom Expression

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Concave-gum disease of citrus is widespread in Corsica (Vogel, 1961; Vogel and Bové, 1962). Practically all Willowleaf mandarin and Washington navel orange trees planted before 1959 are affected and have severe concavities on the trunk, limbs, and branches. In 1963 and 1964 several experiments were started to study the effect of concave-gum infection on tree behavior. The first results are presented here.

EXPERIMENTS AND RESULTS

Effect of concave-gum on mandarin trees. In 1964, buds of a seedling mandarin tree were propagated on 2-year-old sour orange seedlings. Three weeks later, inoculation with the concave-gum pathogen was started according to the schedule in table 1. Two sources of concave-gum inocula were used. One was a 4-year-old Washington navel orange tree propagated from budwood carrying California concave gum 158-62; this tree had shown concave-gum symptoms 3 years after propagation. The second source tree was a 20-year-old mandarin on sour orange rootstock in a Corsican orchard (Mordiconi); this tree had unusually mild symptoms. Some of the mandarin test plants were inoculated with only one of the two concave-gum isolates, others with both. Six plants were used for each treatment. The results are shown in table 1.

All inoculated trees showed young-leaf symptoms within a few months after inoculation. Concavity symptoms began to appear in 1972, 11 years after inoculation. By 1975, all six trees that received the California concave-gum inoculum (treatment 3) showed concavities whereas only one of the six trees that received the Corsican inoculum (treatment 2) was affected. In treatments 4 and 5 the trees were first inoculated with one isolate of concave-gum virus, that used in treatments 2 and 3, respectively, and 6 weeks later with the second, when the trees already showed young-leaf symptoms from the first inoculation. The trees of treatments 4 and 5 have the same symptoms as those of treatments 2 and 3, respectively; six out of six trees first inoculated from the California source have concavities (treatment 5); only one tree out of six first inoculated from the Corsican source has concavities (treatment 4). When both inocula were used at the same time (treatment 6) the results were intermediate; three trees out of six were affected.

Thus, from the number of plants showing symptoms 11 years after inoculation one would tend to conclude that the California isolate of concave gum is more severe than the Corsican one. This conclusion seems to be strengthened by the fact that the "milder" Corsican isolate protects the trees from the more "severe" California isolate (treatment 4 compared to 3). However, a different conclusion is reached when one examines the effect of concave-gum infection on

TABLE 1
SEEDLING MANDARIN TREES ON SOUR ORANGE INOCULATED WITH VARIOUS COMBINATIONS OF TWO CONCAVE-GUM ISOLATES; SYMPTOMS OF CONCAVE GUM AND DEVELOPMENT OF TREES 11 YEARS AFTER INOCULATION

Treatment no.	Concave gum inocula (Mordiconi)	(Cal. 158-62)	Concave-gum* symptoms	Height of trees m	Circumference Scion cm	Stock cm
1	—	—	0/6	3.4	43	38
2	+ (0)†	—	1/6	3.3	39	35
3	—	+ (0)	6/6	3.1	41	37
4	+ (0)	+ (6)‡	1/6	3.0	37	34
5	+ (6)	+ (0)	6/6	3.0	36	33
6	+ (0)	+ (0)	3/6	3.2	41	37

*Number of plants showing symptoms/total number of plants used.
†(0) Inoculated at zero time.
‡(6) Inoculated zero time plus 6 weeks, when the plants already showed young-leaf symptoms from the first inoculation.

tree development rather than on symptom expression. Then the Corsican isolate appears to be more severe in that it causes a greater reduction in stock and scion circumference than the California isolate and there seems to be no cross protection (table 1). Furthermore, the reduction in scion growth due to the Corsican isolate (treatment 2) was observed as early as 1970, 2 years before concave-gum symptoms began to appear. Conversely, with the California isolate the first reduction in scion circumference was noticed late in 1974, two years after concavities appeared. Growth retardation prior to symptom expression was also noticed in treatments 4 and 5 where both isolates of concave gum were introduced.

Effect of various concave-gum isolates on young-line Washington navel trees on sour orange. Two-year-old sour orange seedlings were used as stocks to propagate Washington navel orange buds of the following two parent trees: (1) Old-line Corsican tree AR 22; the tree was 30 years old and showed severe symptoms of concave gum; it also carried the exocortis viroid; (2) Young-line 5-year-old seedling tree "M" from seed from Morocco.

Sour orange seedlings budded with young-line Washington navel were divided into four groups of four plants each. Three of these groups were inoculated each with a different isolate of concave-gum virus (table 2, treatments 3, 4, and 5). For each budded sour orange plant two pieces of concave-gum bark inoculum were used; one was grafted above and the other below the Washington navel bud, the bud and bark inoculum being grafted the same day. The concave-gum inocula came from the following three source trees: (1) Old-line Washington navel tree AR 22, also used as the parent tree for bud propagation (see above); (2) a Washington navel tree infected with California concave gum 158-62; (3) a 50-year-old Willowleaf mandarin tree, AR 56, with strong concave-gum concavities, also infected with exocortis viroid and cachexia-xyloporosis pathogen.

Table 2 shows that 11 years after inoculation two of the three concave gum isolates have induced concavities on all inoculated trees (treatments 2, 3, and 4). Only concave gum isolate AR 56 has not induced symptoms. (In another experiment, not reported here, the same isolate has not caused concave-gum symptoms on Marsh seedless grapefruit, Hamlin sweet orange, or Orlando tangelo 12 years after inoculation; it did, however, cause concavities on Willowleaf mandarin). Despite the fact that the Washington navel trees inoculated with concave-gum isolate AR 56 (treatment 5) showed no symptoms (concavities) of the disease, the circumferences of stocks and scions and the heights of the trees (table 2) indicate that their growth was retarded almost as much as the concavity-affected trees inoculated with concave-gum isolate

TABLE 2
WASHINGTON NAVEL PROPAGATIONS ON SOUR ORANGE INOCULATED WITH VARIOUS CONCAVE-GUM ISOLATES: SYMPTOM EXPRESSION, GROWTH CHARACTERISTICS, AND YIELDS 11 YEARS AFTER INOCULATION

Treatment no.	Washington navel budlines	Isolate	Concave-gum symptoms*	Height of tree m	Circumference Stock cm	Circumference Scion cm	1974 yield kg/tree
1	Young line (M)	—	0/4	3.9	43	41	119
2	Old line (AR 22)	—	4/4	2.6	29	30	60
3	Young line (M)	Old line (AR 22)	4/4	3.7	45	43	123
4	Young line (M)	Concave gum 158-62	4/4	3.2	35	34	116
5	Young line (M)	Concave gum AR 56	0/4	3.2	37	37	96

*Number of plants showing symptoms/total number of plants used.

TABLE 3
OLD-LINE WASHINGTON NAVEL TREES ON SOUR ORANGE OR TROYER CITRANGE WITH OR WITHOUT CONCAVE-GUM VIRUS: SYMPTOM EXPRESSION, GROWTH CHARACTERISTICS, AND YIELDS 12 YEARS AFTER BUDDING

Test plants	Presence of concave gum	Concave gum* symptoms	Height of trees m	Circumference Stock cm	Circumference Scion cm	1974 yield kg/tree
Washington navel on sour orange	—	0/6	2.8	35	33	46
Washington navel on sour orange	Concave gum 158-62	6/6	2.5	30	29	44
Washington navel on Troyer citrange	—	0/6	3.5	48	41	119
Washington navel on Troyer citrange	Concave gum 158-62	6/6	2.9	39	34	65

*Number of trees showing symptoms/total number of trees used.

158-62 (treatment 4). Furthermore, the reduction in growth of the symptomless trees of treatment 4 started as early as 1967, only 1 year later than the concavity-affected trees of treatment 5. The lesser development of the symptomless trees of treatment 5 is thus independent of concave-gum symptoms of concavities.

The exocortis viroid carried by source AR 56 probably is not involved in the stunting since the concave-gum-affected trees of treatment 3 also carry exocortis and are as large as the noninoculated control trees of treatment 1. The cachexia pathogen does not seem to be involved either since it does not affect sweet orange trees on sour orange rootstock. We are thus left with a growth-retardation effect due to concave-gum infection but independent of concave-gum concavities. Not all isolates of concave gum virus seem to induce such a growth reduction; the trees inoculated with concave-gum isolate AR 22 (treatment 3) have grown as well as the noninoculated control trees (treatment 1) even though all trees of treatment 3 have concavities. Concave-gum isolate AR 22 thus appears to be "milder" than isolate AR 56 with respect to tree growth but with respect to concavities it is more severe than isolate AR 56, which has still caused no concavity symptoms.

Finally, table 2 shows that old-line trees from AR 22 (treatment 2), have a much poorer growth than young-line control trees (treatment 1). This difference in growth reflects the increased vigor characteristic of a new line in comparison with the corresponding old line, rather than the presence of concave-gum and exocortis pathogens in the old-line trees, for young-line trees inoculated with the same pathogens (treatment 3) grew as well as the noninoculated controls.

Effect of a concave-gum isolate on old-line Washington Navel trees on sour orange or Troyer citrange rootstocks. In the above experiments, sour orange was the only rootstock used. It seemed of interest to compare sour orange with another concave-gum tolerant rootstock, namely Troyer citrange. Therefore, buds from two different old-line Washington navel orange parent trees were propagated on sour orange and Troyer citrange seedlings. Both parent trees were infected with exocortis viroid, but only one carried the concave-gum pathogen (158-62).

Table 3 shows that 12 years after propagation the trees carrying concave-gum virus all had concavities, irrespective of rootstock. None of the trees on Troyer citrange, with or without the concave-gum pathogen, has shown exocortis bark-scaling symptoms on the rootstock. Only the trees with concave gum have shown young-leaf symptoms.

Table 3 also shows that trees infected with concave-gum pathogen 158-62 are smaller than those free of it, and that the difference between infected and control trees is much greater in those grafted on Troyer citrange than in those on sour orange. The larger difference observed with Troyer citrange rootstock is due to the greater gorwth of control trees on Troyer citrange on sour orange, as is usually the case in Corsica.

Table 4 shows the rate and amount of scion growth from 1965 to 1974. The concave-gum-affected trees on sour orange rootstock began to lag behind the control trees in 1971, 2 years after symptoms appeared. Decreased growth of the concave-gum-infected trees on Troyer citrange started earlier, in 1966, 1 year before symptoms appeared. Again, as in the results shown in tables 1 and 2, no correlation was found between the time when the concave-gum symptoms appeared and the time when reduction in growth became noticeable.

CONCLUSIONS

The results of experiments reported here show that differences exist between the various sources of the concave-gum pathogen used in this work. From the point of view of symptom expression some of the isolates were able to induce

TABLE 4
OLD-LINE WASHINGTON NAVEL TREES ON SOUR ORANGE AND TROYER CITRANGE WITH OR WITHOUT CONCAVE-GUM VIRUS: RATE OF SCION GROWTH

Test plant	Presence of concave gum	Mean scion circumference (cm) in									
		1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Washington navel on sour orange	—	3	5	7	9	14	17	21	26	29	33
Washington navel on sour orange	concave gum 158-62	3	6	8	11	14	17	20	24	27	29
Washington navel on Troyer citrange	—	4	7	11	17	23	28	32	36	39	41
Washington navel on Troyer citrange	concave gum 158-62	4	6	10	14	18	22	26	29	31	34

concave-gum symptoms (concavities) on all inoculated trees within 11 or 12 years after inoculation; others caused symptoms on only part of the inoculated trees within the same length of time; and still others have caused no symptoms on any trees yet. From the point of view of growth reduction, some of the isolates stunted the trees appreciably, while others had little effect on tree development. No correlation was found between severity of growth reduction, based on tree height and trunk circumference, and the severity of symptoms based on the length of time required from symptoms to appear and on the number of concavities produced. Isolates of concave gum which induced concavity symptoms in the shortest time on all inoculated trees affected tree development only slightly, if at all; other isolates caused appreciable growth reduction in the absence of visible concavity symptoms. Thus, the severity of a given concave-gum isolate must be considered not only from the point of view of symptom expression, but also from that of growth reduction. An isolate able to induce strong symptoms is not necessarily one which stunts trees.

A greater effect of concave-gum infection was noticed on Troyer citrange rootstocks than on sour orange; this probably results from the fact that under Corsican conditions trees on Troyer citrange achieve greater growth and higher yields than those on sour orange rootstock. Finally, the severity with which a tree reacts to a given concave-gum isolate probably depends also on the variety or species of the tree involved.

LITERATURE CITED

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