Effect of Virus Diseases on the Growth and Productivity of Citrus Trees

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VIRUS DISEASES cause serious losses to the citrus industries of practically all citrus-growing countries. However, little data is available from research on the actual reduction in growth and productivity of citrus trees resulting from virus diseases. At the Limeira Experiment Station, Brazil, a number of experiments were planned for the purpose of determining the effect of psorosis, exocortis, and xyloporosis viruses on the size and yield of citrus trees. Preliminary results from the first seven years of these experiments are presented and discussed in this paper.

Methods and Results

EXPERIMENT NO. 1.—Buds from a nucellar Baianinha navel orange [*Citrus sinensis* (L.) Osb.] were propagated on healthy 1-year-old nursery seedlings of Rangpur lime (*C. reticulata* var. *austera* hyb.) and Caipira sweet orange. The seedlings were inoculated at the same time with blind buds from virus-infected trees. Treatments were as follows: psorosis, xyloporosis, exocortis, psorosis + xyloporosis + exocortis, and healthy non-inoculated controls. The sources of these viruses were a tree of Do Ceu (Heaven) sweet orange carrying a severe form of psorosis A, but free from exocortis and xyloporosis viruses; a tree of Barão orange infected with xyloporosis, but free of psorosis and exocortis viruses; and a tree of Hamlin orange infected with a severe strain of exocortis, but free of psorosis and xyloporosis viruses. All trees carry the tristeza virus that infects practically all field citrus trees in Brazil. A randomized design of treatments was used with 5 plants per plot and 3 replications. The plants were budded and inoculated in February, 1960. Eighteen months later the trunk circumference 10 cm above the bud-union was recorded for all plants. Differences in the size of the young plants, as indicated by the trunk circumferences, were not significant as shown by the Fisher (F.) test (5).

TABLE 1. Comparative size and yield of 7-year old nucellar Baianinha navel orange trees on Rangpur lime and Caipira sweet orange rootstocks, inoculated with 3 viruses singly and together

Treatments	Average circumference trunk, 1966, cm	Difference in trunk circum., per cent	Total yield[a] thru 1966, number fruits	Difference in yield, per cent
	Trees on Rangpur lime			
Psorosis	27.0	2.2 –	2,635	8.7 –
Xyloporosis	28.3	1.5 +	2,874	0.4 –
Exocortis	26.7	4.3 –	2,854	1.1 –
P + X +E	23.6[b]	15.4 –	3,036	5.9 +
Control	27.9		2,886	
	Trees on Caipira sweet orange			
Psorosis	27.8	0	1,337	29.5 +
Xyloporosis	27.8	0	901	13.5 –
Exocortis	27.1	2.2 –	1,388	33.2 +
P + X + E	26.7	3.6 –	1,160	11.3 +
Control	27.7		1,042	

a. Total yield from 12 trees in each treatment.
b. Significant at 5 per cent level.

The trees were planted in the field in December, 1961, following a split plot design with 2 trees per lot and 6 replications, at a 6 x 6 meter spacing. Average trunk circumference in 1966 and the number of fruits produced in the first 3 crops from the 12 trees in each treatment are shown in Table 1. Rangpur lime is sensitive to exocortis and xyloporosis viruses, whereas Caipira sweet orange is considered tolerant to both. Possibly due to the vigor of the nucellar tops, differences in the sizes of infected and healthy trees were generally slight at this time. Trees on both rootstocks infected with all 3 viruses were 3 to 16 per cent smaller than those infected with a single virus or the healthy controls. Only trunk symptoms of exocortis were observed on the Rangpur lime trees infected with this virus, but great variability was found. Symptoms ranged from minor bark cracking to severe scaling and gumming, and vigor of the trees was inversely related to the severity of the exocortis symptoms (trunk circumference ranged from 21 to 29 cm). Leaf symptoms of psorosis were observed.

Differences in the yields of healthy and virus-infected trees were not significant. However, the yield of trees on the Rangpur lime rootstock was increased by infection with all 3 viruses in the first years of production, possibly due to a girdling effect.

EXPERIMENT NO. 2—Buds of nucellar and healthy old-line Piralima orange trees were propagated on Rangpur lime rootstock. Half of the

TABLE 2. COMPARATIVE SIZE AND YIELD OF HEALTHY AND EXOCORTIS-INFECTED NUCELLAR AND OLD-LINE PIRALIMA SWEET ORANGE TREES ON RANGPUR LIME ROOTSTOCK

Treatments	Average trunk circumference, 1966, cm	Difference in trunk size, per cent	Total yield[a] thru 1966, number fruits	Difference in yield, per cent
		Old-line Piralima		
Exocortis	13.4	30.3 –	1,768	26.4 +
Control	19.2		1,399	
		Nucellar-line Piralima		
Exocortis	22.3	16.5 –[b]	1,050	5.7 –
Control	26.7		1,114	

a. Total yield from 16 trees in each treatment.
b. Significant at the 5 per cent level.

budlings of each type were inoculated with exocortis virus. The source of the exocortis inoculum was the same Hamlin orange tree used in Experiment No. 1. The rootstock seedlings were budded in January, 1961, and the budlings were set out in the field in January, 1962, following a design of randomized blocks with 2 trees per plot and 8 replications. Tree sizes, as indicated by trunk circumferences at 10 cm above the bud-union and the yield in the first 3 crops is summarized in Table 2. At 7 years, the nucellar trees, even when infected with the exocortis virus, were larger than the old-line trees. However, the exocortis-infected trees were markedly smaller than the healthy controls. The girdling effect caused by exocortis infection induced heavier early bearing in the old-line trees, but not in the nucellar line trees.

EXPERIMENT NO. 3.—This experiment was devised to investigate the use of mild strains of the exocortis virus to induce higher early production of orange trees budded on Rangpur lime rootstock without causing great reduction in the growth of the tree. Nucellar Hamlin orange was propagated on 1-year-old Rangpur lime seedlings in the nursery. At the same time, these seedlings were inoculated with blind buds from trees carrying strains of exocortis virus, but free of other known viruses, except tristeza. The exocortis strains used were as follows: 2 very mild strains, 4 mild strains, 1 severe strain, and 1 very severe strain. The severity of the strains was rated according to symptoms produced on Rangpur lime test plants in a previous experiment. Non-inoculated trees were left as controls. The trees were budded in August, 1962, and 16 months later were transplanted to the field in a randomized block design, with 2 trees per plot and 4 replications. Measurements of the trunk circumference in 1966 indicated that the trees infected with severe and very severe strains were slightly smaller than the control plants and those infected with milder strains. Symptoms of exocortis were first observed in the trees infected with the more severe strains of exocortis virus.

OTHER EXPERIMENTS.—Several other experiments as well as field observations in commercial orchards indicate that the reduced growth rate of trees on Rangpur lime rootstock is directly related to the strain of exocortis virus present in the trees and to the incubation period. Exocortis virus always induced early bearing and frequently caused higher early yields than those of the healthy controls. These differences were greater in old line than in the nucellar trees. However, the average fruit production of the first 10 crops was reduced 40 to 70 per cent when trees on Rangpur lime rootstock were affected by severe strains of exocortis virus. On Rangpur lime, xyloporosis virus has a long incubation period, and its effect on the size and yield of trees becomes apparent only 8 or 9 years after infection. No significant reduction in tree size and yield resulted from psorosis virus infection in trees younger than 15 years. Very few orchards in Brazil have trees older than 15 years because tristeza virus virtually destroyed the citrus industry in the years 1940-1952. However, a decline of 6-year-old trees of Piralima orange was recently found associated with psorosis-like scaling of the trunk.

Discussion and Conclusions

Although great effort has been devoted to the study of citrus viruses, little research has been conducted on the effects of virus diseases on the size and yield of infected trees. Moore *et al.* (1, 2), Tidd (7), and Wallace (8) were among the first to report on the effect of viruses on orange yields and the economic loss they cause to the citrus grower. The studies were based on commercial orchards of Valencia and Washington navel oranges affected by the psorosis virus. The effect of progressive stages of this disease reduced yields from .5 to 72 per cent. The control plants in these studies may have also been infected with psorosis, but they exhibited no conspicuous trunk symptoms. Olson *et al.* (3, 4) reported that xyloporosis and exocortis reduced the size of trees on susceptible rootstocks by 70 per cent. Differences in the productivity of healthy and diseased Valencia orange trees on different rootstocks were also reported by these authors, although genetic differences among the orange scions may have affected the yields. Salibe (6) recently reported that tristeza virus reduced the growth of mandarin trees up to 50 per cent on 17 different tristeza-tolerant rootstocks.

The results presented in this paper are preliminary, but suggest the following conclusions: 1) The presence of psorosis, exocortis, and xyloporosis viruses failed to affect the growth of nursery trees on Rangpur lime rootstock to a significant degree. 2) Psorosis virus had little or no significant influence on the size and yields of young citrus trees. 3) Old-line trees on susceptible rootstocks were more severely affected by the presence of exocortis virus than were nucellar line trees. For example, young exocortis-infected trees of old-line and of nucellar-line sweet orange on Rangpur lime rootstocks were, respectively, 30.3 and 16.5 per cent smaller than virus-free trees the same age. 4) The effect of viruses on tree size and yield varies with the rootstock, and the growth and yield of trees on tolerant rootstock may be slightly affected by virus infection.

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