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Journal
International Organization of Citrus Virologists Conference Proceedings (1957-2010), 8(8)

ISSN
2313-5123

Authors
Cohen, M.
Castle, W. S.
Phillips, R. L.
et al.

Publication Date
1980

DOI
10.5070/C597c108rt

Peer reviewed

EXOCORTIS AND GUMMY PITTING

Effect of Exocortis Viroid on Citrus Tree Size and Yield in Florida*

Mortimer Cohen, William S. Castle, Richard L. Phillips, and Dennis Gonsalves

Dwarfed trees in high density plantings have been highly successful in improving efficiency of production and harvesting in deciduous fruit orchards. There has also been much interest in producing dwarfed citrus trees (Phillips, 1969). The potential of small citrus trees resulting from the introduction of exocortis viroid into trees on exocortis sensitive rootstocks has been studied in Australia (Long *et al.*, 1972; Bevington and Bacon, 1977), in Brazil (Pompeu *et al.*, 1976), and in the U.S.A. (Cohen, 1968, 1974). This is a preliminary report on an experiment designed to study the effects of eight exocortis viroid isolates on a number of common citrus cultivars on sensitive rootstocks. Duplicate plantings are located more than 180 km apart at Fort Pierce and Lake Alfred in representative but ecologically different growing areas of Florida.

MATERIALS AND METHODS

Rootstocks used in this experiment were Rubidoux trifoliate orange, Carrizo citrange, and Rangpur lime. Rough lemon and sour orange rootstocks, usually considered to be non-sensitive to exocortis viroid, were used as controls. Rootstock seeds originated from single-tree sources except for seeds of rough lemon which came from a group of registered trees.

Scion cultivars consisted of Valencia and Pineapple orange, Ruby and Marsh grapefruit, and Dancy tangerine. Scion budwood from typical single trees, free of exocortis, xyloporosis, and psorosis pathogens, was provided by the Bureau of Citrus Budwood Registration. Trees were grown in a commercial nursery near Fort Pierce and planted on April 10, 1973 at the Agricultural Research Center, Fort Pierce, and the Agricultural Research and Education Center, Lake Alfred. The plantings at the two locations were identical in tree numbers and treatment combinations, except that Marsh grapefruit trees were planted only at Lake Alfred. Tree rows were 4.6 m apart with 3.8 m between trees within the row at both locations.

Exocortis viroid isolates were first graft-inoculated into the trees 6 months after planting, using bark tissue from appropriate source trees. Three bark chips per tree were used, and a tree was considered inoculated when at least two bark chips were found alive 2 months after inoculation. Because of high inoculum mortality, about a year elapsed before all trees were properly inoculated.

Treatments consisted of eight exocortis isolates and an uninoculated

*Florida Agriculture Experiment Stations Journal Series No. 1767.

check. The isolates were rated as severe or moderate on the basis of the appearance of the source trees. A brief description of the treatments follows, listing the variety of each source tree and the original rating:

A. uninoculated checks
B. Marsh grapefruit; severe
C. Valencia orange; moderate
D. Ruby red grapefruit; severe
E. Valencia orange; moderate
F. Valencia orange; severe
G. Pineapple orange; moderate
H. Duncan grapefruit; severe; this is the viroid of treatment B mechanically transmitted by S. M. Garnsey and introduced into a Duncan grapefruit seedling for increase in inoculum.
I. Pineapple orange; moderate

Treatments G and I were supplied by Don Bridges of the Florida Division of Plant Industry, Bureau of Citrus Budwood Registration.

The experimental design was a randomized complete block with six replications of 2-tree plots for Valencia and Pineapple oranges and Marsh grapefruit and six replications of single-tree plots for Ruby red grapefruit and Dancy tangerine. Because of an error in the inoculation pattern in Dancy tangerines, replication was incomplete for this variety at Lake Alfred.

All nine treatments were used for Valencia and Pineapple orange trees on trifoliate orange and Carrizo citrange at both locations and for Marsh grapefruit trees at Lake Alfred, but fewer treatments were used for trees on Rangpur lime and for the experiments with Ruby red grapefruit and Dancy tangerine. Check trees on rough lemon and sour orange had only two treatments: A and B. The planting at Fort Pierce contained 888 trees and that at Lake Alfred, 1212 trees.

Annual records were made of tree size and fruit yield. Fruit quality was determined at approximately the same date each year. Observations on tree condition and bark scaling below the bud union also were made periodically.

Tree productivity in this experiment was calculated for each treatment using an "efficiency index," $E = \frac{Y}{D^2}$, where D was the mean canopy diameter of trees in any treatment and Y the corresponding mean yield in boxes per tree at the last harvest. E thus measured average productivity for each treatment and variety per m^2 of space required for the average tree in each treatment.

Both plantings were damaged Jan. 20, 1977, by a severe freeze which caused severe dieback and freeze cankers on many trees. Considerable reduction of yield was sustained during the 1977-78 year, but loss of trees was insignificant.

This paper presents only a portion of the data obtained in this experiment.

RESULTS

Information on canopy diameter and yield of Pineapple orange scions on trifoliate orange, Carrizo citrange, and Rangpur lime is given in tables 1 and 2. Data from five of the six replications were used for statistical analysis. Measurements for each rootstock and scion at each location were analyzed separately. When compared with the uninoculated checks, canopy diameter (table 1) was reduced by all inoculation treatments on all three rootstocks, but the greatest dwarfing response occurred on trifoliate orange at Lake Alfred. The strongest effect was produced by isolate D, usually followed by B. Isolate H, mechanically transmitted from B, produced almost the same dwarfing of Pineapple orange trees as B on trifoliate orange, but not on Carrizo citrange. Original designations of isolates as severe or moderate generally predicted the effect of their inoculation on canopy diameter of trees in this experiment (table 1). On trifoliate orange and Rangpur rootstocks, differences in canopy diameter between trees carrying mild isolates and those carrying severe isolates were mainly statistically significant. Size differences of trees on Carrizo citrange were statistically significant at Lake Alfred, but not at Fort Pierce.

Yield response to inoculation (table 2) was similar to canopy diameter effects

TABLE 1
AVERAGE CANOPY DIAMETER (M) OF PINEAPPLE ORANGE TREES IN EXOCORTIS DWARFING EXPERIMENT, SEPTEMBER 1978

	Rootstocks					
	Trifoliate		Carrizo		Rangpur	
Treatment	LA*	FP†	LA	FP	LA	FP
A	1.39	2.04	1.96	1.78	1.87	2.17
B	.79	1.52	1.34	1.47	1.53	1.83
C	1.06	1.91	1.62	1.67	1.52	2.15
D	.69	1.24	1.22	1.49	1.31	1.76
E	.93	1.57	1.55	1.60	1.40	1.94
F	.84	1.43	1.61	1.72		
G	1.17	1.93	1.68	1.85		
H	.82	1.54	1.81	1.65		
I	.90	1.69	1.59	1.70		
M.E.T.‡	.90	1.60	1.55	1.64	1.44	1.92
L.S.D. 5%	.16	.16	.17	NS	.20	.21
L.S.D. 1%	.22	.22	.22	NS	.28	.29

* Lake Alfred
† Fort Pierce
‡ M.E.T. = Mean of exocortis treatments.

TABLE 2
AVERAGE YIELD (BOXES* PER TREE) OF PINEAPPLE ORANGES IN EXOCORTIS DWARFING EXPERIMENT, HARVESTED JANUARY 1979

	Rootstocks					
	Trifoliate		Carrizo		Rangpur	
Treatment	LA†	FP‡	LA	FP	LA	FP
A	.29	.67	.73	.44	.98	.90
B	.20	.25	.55	.32	.37	.53
C	.20	.55	.85	.38	.55	.89
D	.05	.18	.40	.33	.62	.45
E	.12	.27	.68	.37	.37	.75
F	.07	.25	.88	.39		
G	.20	.49	.94	.48		
H	.05	.34	1.08	.47		
I	.12	.42	.60	.45		
M.E.T.§	.13	.34	.75	.40	.48	.66
L.S.D. 5%	NS	.14	.20	NS	.54	.25
L.S.D. 1%	NS	.19	.27	NS	NS	.34

* Oranges in one box weigh 40.8 kg.
† Lake Alfred
‡ Fort Pierce
§ M.E.T. = Mean of exocortis treatments.

except that yield differences for trees on trifoliate orange at Lake Alfred were not statistically different.

Most check trees on rough lemon and sour orange, when all five scion varieties in the experiment were considered, had smaller canopy diameters and produced less fruit when they were carrying exocortis isolate B than when uninoculated (tables 3 and 4).

TABLE 3
AVERAGE CANOPY DIAMETER (M) OF TREES ON ROUGH LEMON AND SOUR ORANGE ROOTSTOCKS, SEPTEMBER 1978

		Rootstocks			
		Rough Lemon		Sour orange	
Scion	Treatment	LA*	FP†	LA	FP
Valencia	A	2.26‡	2.53	2.19 §§	2.47§
	B	2.01	2.44	1.83	2.26
Pineapple	A	1.77	2.32	1.92	2.07
	B	1.86	2.19	1.83	1.98
Dancy	A	2.81	2.80	——	2.62
	B	2.99	2.53	——	2.44
Ruby	A	2.68	2.38	2.77	2.38
	B	2.50	2.29	2.53	2.38
Marsh	A	2.65+	——	2.68	——
	B	2.26	——	2.62	——

* Lake Alfred
† Fort Pierce
‡ Difference statistically significant at the 10 per cent level.
§ Difference statistically significant at the 5 per cent level.
§§ Difference statistically significant at the 1 per cent level.

TABLE 4
AVERAGE YIELD (BOXES PER TREE) OF TREES ON ROUGH LEMON AND SOUR ORANGE ROOTSTOCKS; VALENCIA — MAY 1978, OTHERS — DECEMBER 1978 TO MARCH 1979

		Rootstocks			
		Rough Lemon		Sour orange	
Scion	Treatment	LA*	FP†	LA	FP
Valencia	A	1.71‡	.88	1.03	.81
	B	1.17	.71	.66	.68
Pineapple	A	1.15	.92	1.12	.80
	B	1.03	.90	1.09	.68
Dancy	A	2.19	1.23	——	.97
	B	3.50	.75	——	.74
Ruby	A	2.58	1.38	2.46	1.20
	B	2.37	1.07	2.81	1.17
Marsh	A	3.04	——	3.33	——
	B	2.73	——	2.85	——

* Lake Alfred
† Fort Pierce
‡ Difference statistically significant at the 1 per cent level.

Efficiency indices (E) calculated as previously described were usually higher for Lake Alfred than for Fort Pierce (table 5).

Rootstock bark scaling was more commonly associated with severe exocortis isolates B, D, F, and H than with the moderate isolates, but was seen on at least a few trees of each treatment. Bark scaling was most common on trifoliate rootstock followed by Rangpur and Carrizo. No sharp line could be drawn between trees with and without bark scaling with respect to growth or fruit production.

Fruit quality information was obtained for the past three harvests. There was a tendency for juice from trees inoculated with the most severe isolates to be higher in Brix than juice from uninoculated trees or from those carrying moderate isolates. This tendency has been noted in connection with other trees stunted by exocortis (Cohen, 1974, 1977). No relationship was observed between dwarfing and fruit size.

Phytophthora foot rot was a more serious problem at the Fort Pierce site than at Lake Alfred despite identical origin of the trees. Two years after planting, more than 60 per cent of the trees on rough lemon, 20 per cent on Rangpur lime, and 13 per cent on sour orange had foot rot lesions at Fort Pierce. Four per cent of the trees on Rangpur and 22 per cent on rough lemon at Fort Pierce died of foot rot and were replaced. Foot rot was insignificant at Lake Alfred, so none of the trees there were lost to foot rot.

DISCUSSION

The effect of introducing exocortis isolates into citrus trees in this experiment is probably better gauged from the mean canopy diameters shown in tables 1 and 3 than from fruit yields in tables 2 and 4. Yield in any single year provides, at best, an unreliable indication of tree performance because of tendencies to alternate bearing and the strong influence of transient conditions on the crop in individual years. The freeze of Jan. 1977 strongly affected yield patterns, especially on smaller, weaker trees. Yield data for 1977-78 are unrepresentative, so are not presented.

Mean canopy diameter of Pineapple orange trees for all exocortis treatments on the three rootstocks in table 1 was greater at Fort Pierce than at Lake Alfred, but average yield on Carrizo was larger at Lake Alfred than at Fort Pierce (table 2). The higher yield of the

TABLE 5

EFFICIENCY INDICES FOR PINEAPPLE ORANGE TREES ON THE FIVE ROOTSTOCKS IN THE EXOCORTIS DWARFING EXPERIMENT AT LAKE ALFRED AND FORT PIERCE

	Rootstocks									
Treat-	Trifoliate		Carrizo		Rangpur		Rough Lemon		Sour Orange	
ment	LA*	FP†	LA	FP	LA	FP	LA	FP	LA	FP
A	.150‡	.161	.190	.139	.280	.191	.367	.171	.304	.187
B	.320	.108	.306	.148	.158	.158	.298	.188	.326	.174
C	.178	.151	.324	.136	.238	.193				
D	.105	.117	.269	.149	.361	.145				
E	.139	.110	.283	.145	.189	.199				
F	.099	.122	.339	.131						
G	.146	.132	.333	.140						
H	.074	.143	.330	.173						
I	.148	.147	.237	.158						

* Lake Alfred

† Fort Pierce

‡ Values represent average yield in January 1979 per m^2 of space required for trees. See text for equation and details.

smaller trees on Carrizo at Lake Alfred is reflected in the higher efficiency index rating for trees on Carrizo at Lake Alfred than at Fort Pierce (table 5). The generally higher efficiency indices at Lake Alfred demonstrate that trees at Lake Alfred tended to be denser and more productive than those at Fort Pierce.

Efficiency indices in table 5, calculated from figures in tables 1 to 4, are presented to illustrate the method and to show how it permits comparison of productivity per unit of tree area for different treatments. Efficiency index data which will be obtained when trees are closer to maturity will be helpful for the planning of new high density plantings.

Detailed results in this report are presented mainly for Pineapple orange scions but the effects of the various treatments on other scions in the experiment are generally similar to results on Pineapple. The exocortis isolates used originated from different varieties of orange and grapefruit, but variety of origin did not appear to affect the dwarfing characteristics of the isolate.

Results at both experimental sites show that trees on sour orange and rough lemon rootstocks carrying isolate B were usually smaller and lower-yielding than uninoculated check trees (tables 3 and 4). Differences were statistically significant in only a few cases, reflecting the relatively small differences between treatments. Previous reports also have indicated that trees on "nonsensitive" rootstocks are often stunted by exocortis inoculation (Sinclair and Brown, 1960; Cohen, 1977). These observations indicate that the separation of rootstocks into "sensitive" and "nonsensitive" is artificial and suggest that the use of budwood carrying exocortis isolates in propagating trees on rough lemon, sour orange, and perhaps other "nonsensitive" rootstocks may be worthwhile for obtaining moderate limitation of tree size.

The exocortis dwarfing experiment at Lake Alfred and Fort Pierce needs more time to give results which can be utilized directly in the designing of new high density citrus plantings but is already providing a better understanding of the influence of exocortis viroid on the performance of citrus trees.

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