Interrelation Among Rootstocks, Leaf Composition and Stem Pitting on Sweet Orange Scions

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The virus complex that causes tristeza symptoms is present in almost all citrus-producing areas in the world. However, the rate of spread of the disease, the type, and intensity of symptoms are variable. This variability has been attributed to the differences among vectors and virus strains present in each region (Fraser, 1968).

In those regions where tristeza virus was endemic and susceptible stionic combinations were avoided, other problems arose which were also attributed to the tristeza virus complex. So, there are stem-pitting problems in grapefruit, acid limes, and sweet oranges in Brazil.

The stem-pitting problem received such attention in Brazil, at first because it affected two important varieties, Pera orange and Galego lime (Moreira, 1960); including Rangpur lime, the most important rootstock in the country (Müller *et al.*, 1968). Although the most remarkable symptom of this disease is pitting of the stem, the real economic loss is caused by reduction of growth and yield, and poor quality of the fruit on affected trees. The intensity of stem pitting is not always related to these problems (Donadio and Kfouri Filho, 1979).

Surveys have been published which deal with the susceptibility of scions to stem pitting in Sao Paulo (Salibe, 1965; Donadio *et al.*, 1974) and Rio Grande do Sul (Dornelles, 1976). These surveys allow comparisons among scions in the same situation, but the great variability in the reactions of scion according to rootstock, cultural practices, and locality has been demonstrated (Salibe and Mischan, 1976). Locality is a factor difficult to interpret because it is a complex of several factors, especially related to soil and climate.

The different susceptibilities of rootstocks and scions to stem pitting are well established. The interaction effects of both have been demonstrated (Salibe and Mischan, 1976). Rootstock has a great influence on the scion behavior, depending especially on tissue compatibility, reactions to the climate, and uptake of water and nutrients.

The influence of rootstocks upon scion leaf composition has been thoroughly demonstraed, although there are some differences in published data (Wutscher, 1973). A relation between nutrition and virus symptoms was demonstrated with exocortis (Weathers *et al.*, 1965) and with stem pitting (Salibe and Mischan, 1976).

In the state of Rio Grande do Sul (Brazil), stem pitting associated with stunting, dieback, and small, malformed fruits is a growing problem. It is now impossible to cultivate some sweet orange varieties, like Pera and Natal de Umbigo oranges. In some localities, other varieties such as Bahia, Westin, and Franck oranges, and even Valencia, which is considered highly tolerant of the tristeza virus complex, are difficult to grow. Strongest symptoms occur in plants growing in poor soils, even when they are fertilized with N, P, K, and Ca. We have improved plant behavior with sprays of Zn, Mn, and B. In a previous paper (Dornelles, 1976), Pera orange trees propagated in a locality different from that of their mother trees did not behave like the parent trees with regard to stem-pitting intensity.

References and local observation support the supposition that stem-pitting symptom intensity depends not only on the virus strains, or on the genetic plant characters, but also on local factors. Nutrition is one local factor which can change plant reaction to a virus.

Leaf composition is one of the best indicators of plant nutritional status. Among other factors, leaf composition depends on availability of soil nutrients, on rootstock extraction ability, and on nutritional sprays. The leaf composition is also affected by virus infection. Koller (1975) demonstrated that tristeza virus reduces the translocation of zinc in susceptible varieties.

MATERIALS AND METHODS

Three rootstock experiments were planted at Taquari Experiment Station, with Valencia, Franck, and Pera orange scions. The experiment with Valencia was planted in 1973, and the other two experiments were planted in 1974. The scions were free of known viruses except tristeza, which was endemic. Valencia orange is highly tolerant of stem pitting, Franck orange is tolerant, and Pera orange is highly susceptible. The experiments were planted in randomized blocks, with four replications and two trees per plot. The soil was deep, acid sandy loam, low in fertility. The rootstocks tested were Citranges C-14, C-20, C-32, C-41, and C-65, *Citrus volkameriana*, Brazilian, Florida, and African rough lemons, Caipira sweet orange, Rangpur lime, Troyer Citrange, and Cleopatra mandarin.

In July 1978, 10 leaves from each plant were collected from fruiting terminals following the technique described by Chapman (1960). In the laboratory at the University of Rio Grande do Sul, in Porto Alegre, the levels of the elements P, K, Ca, Mg, Mn, Fe, Cu, and Zn were determined. The results obtained were subjected to analysis of variance, and the averages were compared by Tukey's test.

Four branches with at least three growth flushes were collected from each plant in December 1978. The branches were peeled and the stem-pitting intensity graded from zero (1 = no symptoms) to five (very strong symptoms). The results were subjected to analysis of variance and the averages compared by Tukey's test.

A Valencia orange orchard on Caipira orange rootstock was planted in 1971 in the same type of soil. A fertilization test was begun in 1972. The treatments were three levels of N, two levels of P, and four levels of K applied to the soil. Higher levels (table 4) were multiples of level 1. The elements Zn, Mg, and B were sprayed. Blocks were randomized with four replications and two trees per plot. Leaves and branches were sampled and analyzed as above.

Trunks were measured in all experiments, and the trunk cross-sectional area was used as an indicator of vigor. These data were also subjected to analysis of variance. The stem-pitting ratings obtained in all experiments were compared with the leaf level of each element and with the trunk cross-sectional area.

The results obtained were compared with the review of Wutscher (1973) and with the Chapman standards (1960).

RESULTS AND DISCUSSION

The results obtained in tissue analysis, stem-pitting rating and trunk measurements are shown in tables 1 to 4.

Scion effect upon leaf composition and stem pitting. The foliar levels of P, K, Mg, and Mn were satisfactory, and there were no differences among scions. Cu levels were high because of copper sulfate sprays for control of citrus scab. Ca was low, as was foreseen by soil analysis. Fe levels were lowest in Valencia orange leaves. Zn levels were higher in Pera orange than in Valencia orange. This result disagrees with those obtained by Koller (1975), who observed the highest Zn levels in leaves of tolerant scions when tristeza virus was present. However, Koller worked with young plants in the greenhouse.

The averages of the stem-pitting ratings on the three scions confirmed previous work (Dornelles, 1976). Pera orange is the most-pitted sweet orange scion, and Valencia orange the least.

Rootstock effects upon leaf composition. Leaf composition of the three scions was strongly affected by rootstocks. Significant differences between foliar levels of elements with rootstock were observed. However, Cu level was affected by rootstock only in Valencia orange scions.

Phosphorus: the extent of variation of leaf levels in P was greater in Pera orange than in other scions.

Potassium: Brazilian rough lemon behaved differently from Florida and African rough lemons with regard to uptake of K, Ca, Mg, and Fe.

Calcium: as observed with P, the extent of variation was greater in Pera orange than in other scions.

Magnesium: results were as expected from the literature, except for Brazilian rough lemon.

Zinc: Zn levels were low, as is normal in the region. Results were as expected, except that Caipira sweet orange did not induce low levels of Zn.

Copper: Cu leaf levels were high, and there were no significant differences except in Valencia orange scions.

Manganese: Cleopatra mandarin and Citrange C-20 induced high Mn leaf levels.

Iron: citranges and Brazilian rough lemon induced the highest Fe leaf levels in all scions. Rangpur lime, Florida rough lemon, African rough lemon, and Cleopatra mandarin induced low levels. These data disagree with data in the literature, since rough lemons and Cleopatra mandarin are considered as inducers of high Fe levels. The presence of tristeza virus could have contributed to this disagreement, but there is no evidence to support this supposition.

Rootstock effects upon stem pitting. This effect was lower than foreseen, since significant differences were obtained only in Pera orange. Salibe and Mischan (1976) found significant effects in five scions at Botucatu. Stem-pitting severity at Botucatu was higher than at Taquari, but different scions were used in Botucatu experiments, which could, perhaps, explain the difference in results. The method of attributing rating by personal judgment according to symptom intensity may not be accurate enough to evaluate the virus damage.

Correlations among leaf composition and stem-pitting symptom intensity. In rootstock experiments, few significant correlations were obtained between leaf levels of the analyzed elements and stem-pitting symptom intensity. In Pera orange, stem pitting was negatively correlated with Mg and positively correlated with Fe. In Franck orange scions, it was positively correlated with Fe levels. No correlation was found for Valencia orange scions. There seems to be a greater correlation between leaf composition and stem pitting in most susceptible scions than in tolerant scions.

There is a disagreement between these results and those at Botucatu; Salibe and Mischan (1976) observed a positive correlation to Mn and a negative correlation to Cu. Salibe and Mischan used different scions, and Cu levels were modified by copper sprays at Taquari.

Tree growth, as measured by trunk cross-sectional area, showed significant differences with all scions, but in no case was there a correlation between cross-sectional area and stem-pitting severity.

Fertilization effect on stem-pitting intensity. Leaf analyses of the fertilization experiment showed significant differences in leaf levels of P, K, Ca, Mg, and Mn. There were no significant differences in leaf levels of Zn, Cu, and Fe. There were no significant differences among trunk cross-sectional areas.

Highly significant differences were obtained with stem-pitting intensity. Apparently, better-fertilized trees showed more intense symptoms, which disagreed with orchard observations. Fertilized trees performed better than check trees which were less pitted. There was no correlation between stem-pitting intensity and trunk cross-sectional area, which agreed with results obtained by Weathers *et al.* (1965) with exocortis symptom expression.

There was a positive correlation between stem pitting and leaf levels of P, K, and Mn. These correlations confirm information in the preceding paragraph, but, in contrast, there was the negative correlation of Mn level

TABLE 1

COMPARISON OF LEAF COMPOSITION, STEM-PITTING RATING, AND TRUNK CROSS-SECTIONAL AREA OF PERA ORANGE TREES ON DIFFERENT ROOTSTOCKS

	Leaf composition								Trunk section	Stem pitting*
	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)	area (cm^2)	
Rootstocks:										
C - 14	0.104	1.01	2.42	0.350	13	55	28	124	20	3.1
C - 20	0.128	1.01	2.52	0.366	15	63	54	130	30	2.5
C - 32	0.132	1.13	2.27	0.365	13	61	24	207	24	3.7
C - 41	0.154	1.29	2.08	0.296	14	48	17	160	35	3.8
C - 65	0.138	1.10	1.96	0.352	13	43	26	165	33	3.7
Volkamer lemon	0.112	1.00	3.13	0.279	14	65	37	124	46	2.7
Brazilian rough lemon	0.122	1.29	2.25	0.238	15	50	30	165	52	3.7
Florida rough lemon	0.110	0.82	3.55	0.352	18	57	35	119	44	3.1
African rough lemon	0.103	0.80	4.12	0.321	18	62	34	120	47	3.5
Caipira orange	0.131	1.04	2.89	0.284	16	49	22	127	48	3.3
Rangpur lime	0.116	1.04	2.95	0.278	15	67	33	106	42	3.3
Troyer citrange	0.147	0.91	2.82	0.394	14	58	18	143	43	3.3
Cleopatra mandarin	0.122	0.83	3.57	0.365	17	69	55	156	38	3.3
Mean	0.124	1.02	2.81	0.326	15	57	32	139	39	3.3
Significance level	1%	1%	1%	1%	1%	N.S.	1%	1%	1%	1%
MSD†	0.031	0.42	0.91	0.100	3.6	—	13	48	25	1.2
Correlation index to stem-pitting rating	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	-3.11	+4.63	N.S.	—

* See text for explanation of rating.

† Minimum significant difference at 95% level (Tukey).

TABLE 2

COMPARISON OF LEAF COMPOSITION, STEM-PITTING RATING, AND TRUNK CROSS-SECTION AREA OF FRANCK ORANGE TREES ON DIFFERENT ROOTSTOCKS

	Leaf composition								Trunk section area	Stem pitting*
	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)	(cm^2)	
Rootstocks:										
C-14	0.120	0.84	2.78	0.411	12.0	27	18	170	17	1.4
C-20	0.150	1.10	2.64	0.386	12.5	33	55	146	23	1.7
C-32	0.137	1.02	2.68	0.433	14.2	47	21	189	21	1.4
C-41	0.146	1.08	2.72	0.313	11.5	44	18	183	36	1.6
C-65	0.141	0.99	2.96	0.399	12.8	40	24	158	29	1.7
Volkamer lemon	0.135	1.09	3.06	0.316	14.0	49	38	134	45	1.5
Brazilian rough lemon	0.140	1.11	2.78	0.298	15.5	42	26	162	41	1.5
Florida rough lemon	0.130	0.83	3.58	0.411	16.0	31	44	154	39	1.6
African rough lemon	0.126	0.91	3.57	0.414	15.8	42	40	155	42	1.4
Caipira orange	0.150	1.10	2.72	0.299	12.8	39	24	135	49	1.3
Rangpur lime	0.133	0.92	3.49	0.330	14.8	46	38	123	38	1.5
Troyer citrange	0.158	0.87	3.08	0.473	12.3	47	18	135	35	1.2
Cleopatra mandarin	0.139	0.86	3.60	0.458	15.8	45	68	127	40	1.1
Mean	0.139	0.98	3.05	0.380	13.8	41	33	151	35	1.4
Significance level	5%	5%	1%	1%	1%	N.S.	1%	1%	1%	N.S.
MSD†	0.037	0.35	0.78	0.109	4.2	—	24	52	21	—
Correlating index to stem-pitting rating	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	+0.26	N.S.	—

* See text for explanation of rating.

† Minimum significant difference at 95% level (Tukey).

TABLE 3

COMPARISON OF LEAF COMPOSITION, STEM-PITTING RATING, AND TRUNK CROSS-SECTIONAL AREA OF VALENCIA ORANGE TREES ON DIFFERENT ROOTSTOCKS

	Leaf composition								Trunk section	Stem pitting*
	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)	area (cm^2)	
Rootstocks:										
C-14	0.127	1.11	2.78	0.370	8.8	71	23	128	32	1.1
C-20	0.153	1.31	2.69	0.315	12.0	84	60	118	36	1.1
C-32	0.144	1.32	2.53	0.389	10.3	118	17	181	35	1.0
C-41	0.147	1.38	2.53	0.312	11.0	86	13	149	54	1.3
C-65	0.139	1.29	2.41	0.360	9.8	95	22	163	32	1.2
Volkamer lemon	0.133	1.27	3.20	0.304	11.3	68	39	93	61	1.3
Brazilian rough lemon	0.127	1.48	2.58	0.263	11.3	71	18	139	67	1.0
Florida rough lemon	0.125	1.14	3.67	0.333	12.5	62	35	105	62	1.0
African rough lemon	0.131	1.15	3.74	0.320	11.8	63	32	108	53	1.0
Caipira orange	0.145	1.32	2.99	0.271	11.8	73	20	117	67	0.8
Rangpur lime	0.131	1.40	3.27	0.280	11.0	65	44	90	53	0.7
Troyer citrange	0.149	1.11	3.00	0.417	10.5	74	12	124	56	1.0
Cleopatra mandarin	0.133	1.10	3.38	0.390	12.3	65	60	114	50	1.1
Mean	0.137	1.26	2.98	0.332	11.1	76	30	125	50	1.0
Significance level	1%	1%	1%	1%	1%	1%	1%	1%	1%	N.S.
MSD†	0.025	0.25	1.04	0.098	2.1	33.34	19	37.8	18	—
Correlation index to stem-pitting rating	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	—

* See text for explanation of rating.

† Minimum significant difference at 95% level (Tukey).

TABLE 4

VALENCIA ORANGE*, FERTILIZATION EFFECTS ON LEAF COMPOSITION, STEM-PITTING RATING, AND CROSS-SECTIONAL AREA

	Leaf composition								Trunk section	Stem pitting*
	P (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)	area (cm^2)	rating†
Treatments‡										
$N_0P_0K_0$	0.114	1.08	3.63	0.288	10	51	10	139	34	0.53
$N_0P_1K_1$	0.137	1.31	3.58	0.236	13	48	11	138	43	0.78
$N_1P_1K_1$	0.138	1.01	3.66	0.276	11	49	15	126	46	1.00
$N_2P_1K_1$	0.126	1.11	3.60	0.286	12	51	18	129	44	0.80
$N_3P_1K_1$	0.129	1.19	3.24	0.303	12	45	16	118	43	1.05
$N_1P_0K_1$	0.107	1.22	3.20	0.236	12	51	13	131	42	0.75
$N_1P_1K_2$	0.124	1.32	3.33	0.245	11	51	14	131	44	1.05
$N_1P_2K_1$	0.124	1.07	3.73	0.279	14	46	15	122	43	0.93
$N_1P_1K_0$	0.125	0.83	3.88	0.346	12	42	13	137	44	0.95
$N_1P_1K_3$	0.132	1.59	3.01	0.209	12	50	13	139	44	0.95
$N_1P_2K_2$	0.133	1.31	3.55	0.240	7	56	15	140	39	1.25
$N_1P_2K_2$ Zn	0.129	1.17	3.59	0.255	12	51	14	129	46	0.90
$N_1P_2K_2$ Mn	0.126	1.37	3.55	0.246	11	45	22	122	53	1.18
$N_1P_2K_2$ Bo	0.131	1.40	3.48	0.253	12	46	13	124	50	1.18
Mean	0.127	1.21	3.50	0.264	11	48	14	130	43	0.95
Significance level	1%	5%	1%	1%	N.S.	N.S.	1%	N.S.	N.S.	1%
MSD§	0.023	0.66	0.62	0.082	—	—	3.6	—	—	0.44
Correlation index to stem-pitting grade	+0.500	+0.238	N.S.	N.S.	N.S.	N.S.	+0.247	N.S.	N.S.	—

* Caipira orange rootstock.

† Scale of 0 to 5, with 5 = to very severe pitting.

‡ Numbers indicate levels of each element/tree: in 1977/78, for N, 1 =375g, 2 = 650g, and 3 = 975g; for P, 1 = 325g P_2O_5 and 2 = 650g P_2O_5; for K, 1 = 325g K_2O, 2 = 650g K_2O, and 3 = 975g K_2O. In prior years, smaller but proportionate amounts were used.

§ Minimum significant difference at 95% level (Tukey).

with stem pitting in the experiment with Pera orange scions. In these two cases, differences in scions and the fact that Mn was applied by spraying in the fertilization experiment, and not in the rootstock experiments, must be pointed out.

CONCLUSIONS

The results obtained in this work cannot be easily interpreted. Disagreements with the results obtained by other authors can be explained by genetic or local differences or by differences in methodology.

The most important observations are:

1. The rating scale for stem pitting is not a good method to evaluate the damage of the tristeza virus complex to susceptible scions.
2. Brazilian rough lemon behaves differently from Florida and African rough lemons with respect to scion leaf composition.
3. Correlation between leaf composition and stem-pitting intensity is greater in the more-susceptible scions, as in the influence of the rootstock upon stem-pitting intensity.
4. Fertilization increases stem-pitting severity, which is positively correlated with P and K levels.
5. There is correlation between Mn leaf levels and stem-pitting intensity, but variation in results does not permit a conclusion to be drawn.
6. There is no correlation between tree vigor and stem-pitting intensity.
7. Fe leaf level is positively correlated with stem pitting in susceptible scions.

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