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Saturated and Mono-Unsaturated Long-chain Hydrocarbon Profiles from Juice Sacs of Mandarin, Tangelo and Mandarin x Tangelo Hybrids[1]

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Abstract. **Saturated and mono-unsaturated hydrocarbons (C_{20}–C_{35}) were examined in juice sacs of 'Clementine' mandarin (*Citrus reticulata* Blanco), 'Orlando' and 'Minneola' tangelos (*C. paradisi* Macf. x *C. reticulata* Blanco), and 'Osceola', 'Lee', 'Robinson', 'Nova' and 'Page' hybrids [*C. reticulata* x (*C. paradisi* x *C. reticulata*)]. 'Clementine' had saturated and monoene profiles similar to those previously reported for mandarins. In the 5 mandarin x tangelo hybrids, linear hydrocarbons accounted for ca. 47% of the saturates and more than 70% of the monoenes. The major saturated hydrocarbons were C_{23} and C_{25}. Except for 'Nova' all hybrids showed a greater total percentage of C_{25} over C_{23}. The C_{23}/C_{25} ratio of 'Nova' (1.53) was more like that of its tangelo than its mandarin parentage. Prominent amounts of C_{25}, C_{27}, C_{29} and C_{31} were present in the monoene fraction. All 5 'Clementine' x tangelo hybrids can be differentiated from each other by their linear, monoene components. Based on these profiles, 'Osceola' and 'Page' appeared to be more like their mandarin than their tangelo parent.**

The uniqueness and relative distribution of secondary plant constituents may assist in determining the position of a plant species, genus or family in a phylogenetic classification. Studies of the chemical constituents of citrus fruits are beginning to be of considerable importance in discerning evolutionary relationships and refining systematic plant classification. In recent years considerable interest has been generated in correlating morphological, biochemical and flavor properties of citrus cultivars with secondary plant constituents (1, 4, 17). Extensive research of citrus long-chain hydrocarbons (5, 6, 7, 8, 9, 10, 11, 12, 13) has shown these lipid end products to be useful in distinguishing citrus taxa.

Four mandarin classes (3), as well as hybrid cultivars of these classes, were recently differentiated based on the relative distribution of their juice sac long-chain hydrocarbons (5, 6, 9, 12, 13). The purpose of the following study was to determine whether 5 commercially important mandarin hybrids (2, 14, 15, 16), viz. 'Lee', 'Robinson', 'Osceola', 'Nova' and 'Page', could be chemically grouped or distinguished.

'Clementine' (*C. reticulata* Blanco), one of the parents of all 5 hybrids, originated as an accidental hybrid in Algeria and was introduced in Florida as budwood in 1909 (3). 'Clementine' has early maturing fruit. 'Clementine' crossed with 'Orlando' tangelo (*C. paradisi* Macf. x *C. reticulata* Blanco) yielded 'Robinson', 'Lee', 'Osceola' and 'Nova' hybrids. 'Robinson', released for commercialization in 1959 (14), produces mature fruit earlier (in Florida) than its 3 sister hybrids. Because of "Robinson's" oblate shape, it resembles 'Dancy' tangerine more than do the other 3 hybrids. 'Osceola' and 'Lee' were also released in 1959 (14). 'Nova', released in 1964 (16), resembles the 'Orlando' tangelo parent. 'Page', the fifth hybrid, was produced by crossing the 'Minneola' tangelo (*C. paradisi* x *C. reticulata*) with 'Clementine'. 'Page', released in Florida by USDA in 1963 (15), is an early maturing, round-shaped fruit which has been commonly referred to as "Page orange." The attachment of orange to 'Page' does not imply *Citrus sinensis* inheritance, although some of its morphological characteristics resemble those of orange.

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A major question to be answered in this study is whether long-chain hydrocarbon profiles can be used to indicate parental influence within hybrids. Specifically, will these hybrid profiles be more characteristic of mandarin (9, 12, 13) than 'Duncan' x 'Dancy' tangelo (9) profiles or will they be different from both parents and from various citrus taxa.

Materials and Methods

Samples of mature 'Clementine', 'Osceola', 'Lee', 'Robinson', 'Nova' and 'Page' fruit were from Whitmore Foundation Farm (U. S. Horticultural Research Laboratory, USDA, Orlando, Florida). The hydrocarbons in the lipids of the fruit juice sacs were isolated, purified and hydrogenated as reported previously for other cultivars (10). The hydrocarbons (saturates and monoenes hydrogenated to saturates) were analyzed by GLC with a Model 7610A FID gas chromatograph (Hewlett Packard, Avondale, Pennsylvania). The analyses were determined on a glass column (3.05 m x 4 mm i.d.) coated with 3% SP-1000 (Supelco, Inc., Bellefonte, Pennsylvania) on 100-120 mesh Gas Chrom Q. The injection port and detector were at 260°C. He flow was 80 ml/min at 2.8 kg/cm^2. The sample (1.5-4.5λ representing 1-10% hydrocarbon in hexane) was injected on-column at 160°C, programmed at 2°/min to 180°C, then 4°/min to 250°C.

Quantitative measurements were obtained with an electronic System IV computing integrator for chromatography (Autolab Inc., Mountain View, California). Representative hydrocarbon samples from previous studies (9, 12, 13) were also injected to correlate data obtained by disc integration quantitations and by

Table 1. Hydrocarbon concn (±SD) in juice sacs of 'Clementine' mandarin and 5 of its hybrids (mg/20g dry wt).

Cultivar	Hydrocarbon			Ratio
	Total	Saturated	Monoene	sat./mono.
Clementine	5.4 ± 0.1	4.4 ± 0.1	1.0 ± 0.1	4.4
Lee	4.1 ± 0.2	3.7 ± 0.1	0.4 ± 0.2	9.3
Osceola	3.7 ± 0.2	3.4 ± 0.1	0.3 ± 0.2	11.3
Robinson	3.9 ± 0.2	3.7 ± 0.2	0.2 ± 0.1	18.5
Nova	9.6 ± 0.2	8.6 ± 0.2	1.0 ± 0.2	8.6
Page	8.5 ± 0.2	7.8 ± 0.2	0.7 ± 0.1	11.1

Table 2. Saturated long-chain hydrocarbon profiles (wt %) of juice sacs of 'Clementine' × tangelo hybrids and their parents.

	Carbon number																		
	Odd-numbered								Even-numbered										
Cultivar	21	23	25	27	29	31	33	35	20	22	24	26	28	30	32	36	Total odd	Total even	Total
Linear																			
A. 'Clementine'	0.40	15.97	20.49	6.91	2.21	0.74	0.42	0.08	0.51	2.15	6.58	4.41	1.46	0.77	0.04	tr[y]	47.22	15.92	63.14
B. 'Orlando[z]'	0.90	14.10	9.73	1.49	0.79	0.65	0.28	0.03	0.38	2.51	4.96	1.22	0.48	0.43	0.14	0.11	27.97	10.23	38.20
1. 'Osceola'	0.33	13.61	19.36	5.30	1.73	1.53	0.31	–[x]	0.29	1.34	7.14	3.62	1.06	0.59	0.38	tr	42.17	14.42	56.59
2. 'Lee'	0.48	17.01	14.98	2.59	0.54	0.23	tr	–	0.19	2.09	6.50	2.42	0.56	0.19	0.04	–	35.83	11.99	47.82
3. 'Robinson'	0.51	16.51	17.24	4.04	0.97	0.45	0.05	tr	0.28	2.55	6.50	3.44	0.68	0.42	0.04	tr	39.77	13.91	53.68
4. 'Nova'	0.94	20.09	13.08	2.18	1.53	2.02	0.41	–	0.48	2.88	5.50	1.56	0.57	0.47	0.18	–	40.25	11.64	51.89
Avg. 1-4 Hybrids	**0.57**	**16.81**	**16.17**	**3.53**	**1.19**	**1.06**	**0.19**	–	**0.31**	**2.22**	**6.40**	**2.76**	**0.71**	**0.42**	**0.16**	**tr**	**39.51**	**12.99**	**52.50**
C. 'Minneola[z]'	0.77	16.37	10.42	1.31	0.50	0.46	0.10	tr	0.15	2.74	5.66	1.22	0.42	0.40	0.14	tr	29.93	10.73	40.66
1. 'Page'	0.93	11.66	15.79	3.66	1.44	1.34	0.36	–	0.85	2.54	6.11	3.21	1.16	0.87	0.40	tr	35.18	15.14	50.32
Iso-branched																			
A. 'Clementine'	0.04	5.12	9.83	2.61	0.59	0.25	tr	–	0.02	0.04	1.25	0.76	0.15	0.13	tr	–	18.44	2.35	20.79
B. 'Orlando[z]'	tr	17.93	15.97	2.76	0.46	0.18	tr	–	tr	0.21	4.34	0.99	0.14	0.17	tr	–	37.30	5.85	43.15
1. 'Osceola'	0.08	4.45	17.18	4.09	0.93	0.40	tr	–	0.15	0.04	2.44	0.43	0.17	0.07	tr	–	27.13	3.30	30.43
2. 'Lee'	0.04	8.99	16.65	3.87	0.47	0.19	–	–	0.03	tr	3.27	1.04	0.11	0.04	tr	–	30.21	4.49	34.70
3. 'Robinson'	0.11	9.54	14.17	3.41	0.57	0.22	tr	–	0.09	0.16	2.39	0.25	0.12	0.10	tr	–	28.02	3.11	31.13
4. 'Nova'	0.05	12.86	11.65	2.43	0.31	0.20	tr	–	0.08	0.32	2.01	0.25	0.19	0.06	tr	–	27.50	2.91	30.41
Avg. 1-4 hybrids	**0.07**	**8.96**	**14.91**	**3.45**	**0.57**	**0.25**	**tr**	–	**0.09**	**0.13**	**2.53**	**0.49**	**0.15**	**0.07**	**tr**	–	**28.22**	**3.45**	**31.67**
C. 'Minneola[z]'	tr	17.06	14.76	3.11	0.53	0.14	tr	–	tr	0.17	3.83	1.05	0.17	0.21	0.05	–	35.60	5.48	41.08
1. 'Page'	0.11	7.81	16.16	5.11	0.86	0.51	tr	–	0.09	0.14	1.77	1.18	0.21	0.27	0.09	–	30.56	3.75	34.31
Anteiso-branched																			
A. 'Clementine'	tr	tr	2.50	1.07	0.18	0.16	tr	–	0.02	0.04	4.17	6.13	1.42	0.38	tr	–	3.91	12.16	16.07
B. 'Orlando[z]'	tr	tr	3.42	1.10	0.13	0.04	tr	–	tr	0.10	7.81	4.86	0.85	0.23	0.11	–	4.69	13.96	18.65
1. 'Osceola'	tr	tr	1.82	0.79	0.27	0.08	tr	–	0.05	0.20	3.34	4.89	1.20	0.34	tr	–	2.96	10.02	12.98
2. 'Lee'	tr	tr	0.83	0.28	0.11	tr	–	–	0.02	0.03	7.09	7.28	1.55	0.29	tr	–	1.22	16.26	17.48
3. 'Robinson'	tr	tr	2.12	0.79	0.19	0.03	tr	–	0.03	0.11	5.72	4.39	1.49	0.32	tr	–	30.13	12.06	15.19
4. 'Nova'	tr	tr	1.44	0.41	0.07	tr	tr	–	0.06	0.48	8.66	5.19	1.10	0.29	tr	–	1.92	15.78	17.70
Avg. 1-4 hybrids	**tr**	**tr**	**1.55**	**0.57**	**0.16**	**0.04**	**tr**	–	**0.04**	**0.21**	**6.20**	**5.44**	**1.34**	**0.31**	**tr**	–	**2.31**	**13.53**	**15.84**
C. 'Minneola[z]'	tr	tr	3.20	0.84	0.14	0.11	tr	–	tr	0.08	7.56	4.90	1.03	0.26	0.14	–	4.29	13.97	18.26
1. 'Page'	0.01	tr	1.17	0.83	0.26	0.20	tr	–	0.03	0.08	4.94	5.22	1.57	0.55	0.51	–	2.47	12.90	15.37

[z]Values reproduced from Ref. 8.

[y]Trace, less than 0.01%.

[x]Not detected under GLC parameters but may be present below 0.001%.

triangulation with the computing integrator data presented in this study.

Each value in Tables 2 and 3 represents the mean of 5-10 determinations. The coefficient of variation (CV) for several mean ranges (MR) showed the following: MR = 0.01-0.10, CV = 10-35%; MR = 0.1-1.0, CV = 5-10%; MR = 1.0-5.0, CV = 3-5%; MR > 5.0, CV < 2%.

Results and Discussion

Table 1 shows the concn of long-chain hydrocarbons in 'Clementine' and its 5 hybrids. Total hydrocarbon concn of 'Clementine', 'Lee', 'Osceola' and 'Robinson' ranged from 3.7 to 5.4 mg/20 g dry wt of juice sacs. This range has been previously observed for mandarins (12, 13). 'Nova' and 'Page' with 9.6 and 8.5 mg, respectively, had concn noticeably higher. The ratios of saturated to mono-unsaturated hydrocarbons ranged from 8.6 ('Nova') to 18.5 ('Robinson') for the 5 hybrids. This range has been observed for mandarin × mandarin crosses (13). The ratio of 4.4 for the 'Clementine' parent is similar to ratios reported for other mandarins, viz. 3.1 for 'Dancy' (9), 4.7 for 'Mediterranean' (13), 3.2 for 'Honey' (13) and 2.9 for 'Kawano Wase' (12). Thus, such values for this ratio appear to be characteristic for mandarins.

Table 2 shows that the percentages of total saturated linear hydrocarbons for 'Osceola', 'Lee', 'Robinson' and 'Nova' were between their parents, 'Clementine' and 'Orlando'. Likewise, 'Page' was intermediate between its parents, 'Minneola' and 'Clementine'. Odd-numbered hydrocarbons accounted for most of this group, with C_{23} and C_{25} predominating. The total percentages of linear odd-numbered (35.2-42.2) and even-numbered (11.5-15.1) hydrocarbons for hybrids were between those of their parents.

Linear saturated C_{23}/C_{25} ratios have been intrinsic for each citrus species previously tested (6, 8). The C_{23}/C_{25} value of the 'Clementine' parent (0.78) was within the mandarin range of 0.50-0.81 and similar to that of 'Mediterranean' mandarin, 0.79 (13). The values for the two tangelo parents are 'Orlando', 1.45 and 'Minneola', 1.57. The C_{23}/C_{25} ratios for the 5 hybrids fell within the range of .70-1.54. 'Clementine' differed noticeably from the two tangelo parents, 'Orlando' and 'Minneola', mainly in its relative percentages of C_{25}, C_{27} and C_{29}. With one exception, C_{29} for 'Lee', the percentages of these 3 hydrocarbons for all hybrids were between those of their parents.

Approximately 20-40% of the saturated hydrocarbon fractions were of the *iso*-branched configuration with odd-numbered carbons predominating. Without exception for total odd- (27.1-30.6%) and even numbered (2.9-4.5%), *iso*-branched structures, all hybrid percentages were between those of their parents. The value of 20.8% for total saturated *iso*-branched paraffins in 'Clementine' is similar to values previously reported for mandarin (9, 13). The major *iso*-branched paraffins were C_{23}, C_{24}, C_{25} and C_{27}; collectively they comprised ca. 93% of the total *iso*-branched group. With the exception of 'Osceola', the percentage of *iso*-C_{23} for the hybrids were between those of the parents. The percentages for *iso*-C_{23}, -C_{25}, -C_{27} and -C_{29} can be used to differentiate these 'Clementine' × tangelo hybrids from sweet oranges (5, 6, 10), lemons (11), limes (8), mandarin × grapefruit hybrids (9), satsuma mandarins (12) and mandarin × mandarin hybrids (13). These four *iso* hydrocarbons cannot, however, be used to differentiate the 5 hybrids

Table 3. Mono-unsaturated long-chain hydrocarbon profiles of juice sacs (wt %) of 'Clementine' x tangelo hybrids and their parents

	Carbon number																		
	Odd-numbered								Even-numbered										
Cultivar	21	23	25	27	29	31	33	35	20	22	24	26	28	30	32	34	Total odd	Total even	Total
Linear																			
A. 'Clementine'	0.24	0.97	9.65	10.18	32.47	27.04	0.83	tr	2.74	1.75	1.47	1.51	1.38	2.05	0.36	tr	81.38	11.26	92.64
B. 'Orlando[z]'	0.66	8.87	28.52	11.26	5.26	1.35	0.12	tr	3.04	1.53	6.04	2.16	1.00	0.27	tr	tr	56.04	14.14	70.18
1. 'Osceola'	0.13	0.73	12.54	13.20	29.01	26.84	2.34	–	1.08	0.75	0.92	1.85	1.54	1.98	0.38	tr	84.79	8.50	93.29
2. 'Lee'	0.25	2.03	27.71	18.63	16.63	8.37	1.00	tr	1.00	0.75	1.98	2.94	1.36	1.01	0.18	tr	74.62	9.22	83.84
3. 'Robinson'	0.48	2.83	34.04	23.71	3.88	1.17	–	–	2.93	1.64	2.71	5.17	1.88	0.27	tr	–	66.11	14.60	80.71
4. 'Nova'	0.98	7.50	25.10	12.35	7.85	13.57	tr	–	1.28	1.34	3.38	2.72	1.49	1.49	tr	–	67.35	11.70	79.05
Avg. 1–4 hybrids	**0.46**	**3.27**	**24.85**	**16.97**	**14.34**	**12.49**	**0.84**	**tr**	**1.57**	**1.12**	**2.25**	**3.17**	**1.57**	**1.19**	**0.14**	**tr**	**73.22**	**11.01**	**84.22**
C. 'Minneola[z]'	1.17	9.38	29.59	12.36	4.02	2.44	0.11	tr	1.14	1.83	5.31	2.76	1.11	1.95	tr	tr	59.07	14.10	73.17
1. 'Page'	0.29	3.78	20.94	17.88	16.58	7.74	0.10	–	1.48	1.65	2.57	3.38	2.19	1.17	0.06	–	67.31	12.50	79.81
Iso-branched																			
A. 'Clementine'	tr	0.11	0.78	0.44	0.14	0.04	tr	–	tr	0.06	0.10	0.13	tr	tr	tr	–	1.51	0.29	1.80
B. 'Orlando[z]'	0.52	4.09	7.92	2.58	0.21	0.07	–	–	tr	tr	0.62	0.92	0.11	0.30	–	–	15.39	1.95	17.34
1. 'Osceola'	0.02	0.07	1.53	1.07	0.29	0.26	tr	–	0.08	0.03	0.04	0.13	0.06	0.02	tr	tr	3.24	0.36	3.60
2. 'Lee'	0.12	0.60	3.62	2.52	0.29	0.57	–	–	0.34	0.07	0.27	0.26	0.09	tr	tr	–	7.72	1.03	8.75
3. 'Robinson'	0.22	0.59	4.19	2.68	0.72	tr	–	–	0.25	tr	0.23	0.54	0.18	tr	–	–	8.40	1.20	9.60
4. 'Nova'	0.15	1.28	5.06	1.65	0.54	1.39	–	–	0.54	0.21	0.51	0.23	0.35	tr	tr	–	10.07	1.84	11.91
Avg. 1–4 hybrids	**0.13**	**0.64**	**3.60**	**1.98**	**0.46**	**0.56**	**–**	**–**	**0.30**	**0.08**	**0.26**	**0.29**	**0.17**	**tr**	**tr**	**–**	**7.36**	**1.11**	**8.47**
C. 'Minneola[z]'	0.11	3.19	6.31	2.79	0.34	0.33	–	–	tr	0.15	0.85	0.69	0.20	0.07	–	–	13.07	1.96	15.03
1. 'Page'	0.73	0.71	3.16	1.71	0.59	0.28	tr	–	0.50	0.15	0.25	0.13	0.09	0.06	tr	–	7.18	1.18	8.36
Anteiso-branched																			
A. 'Clementine'	0.41	0.46	0.40	0.38	0.21	0.06	tr	–	0.69	0.57	0.54	1.12	0.43	0.20	0.09	–	1.92	3.64	5.56
B. 'Orlando[z]'	0.94	1.38	1.52	0.64	0.17	0.08	–	–	0.49	0.78	2.08	3.48	0.83	0.09	–	–	4.73	7.75	12.48
1. 'Osceola'	0.06	0.07	0.22	0.38	0.21	0.03	tr	–	0.08	0.22	0.26	1.13	0.36	0.09	tr	tr	0.97	2.14	3.11
2. 'Lee'	0.23	0.27	0.53	0.58	0.17	tr	–	–	0.41	0.28	0.85	2.30	1.01	0.35	0.43	–	1.78	5.63	7.41
3. 'Robinson'	0.47	0.55	0.82	1.60	0.30	tr	–	–	0.51	0.52	0.72	2.94	1.00	0.26	–	–	3.74	5.95	9.69
4. 'Nova'	0.13	0.44	0.63	0.78	0.43	0.21	–	–	0.49	0.34	1.73	2.33	1.14	0.39	tr	–	2.62	6.42	9.04
Avg. 1–4 hybrids	**0.22**	**0.33**	**0.55**	**0.84**	**0.28**	**0.06**	**–**	**–**	**0.37**	**0.34**	**0.89**	**2.18**	**0.88**	**0.27**	**0.11**	**–**	**2.28**	**5.04**	**7.31**
C. 'Minneola[z]'	0.34	1.07	2.00	0.70	0.16	0.14	–	–	0.49	0.49	2.86	1.90	1.44	0.21	–	–	4.41	7.39	11.80
1. 'Page'	tr	0.67	0.94	0.96	0.79	0.40	tr	–	0.68	0.69	1.75	2.74	1.43	0.78	tr	–	3.76	8.07	11.83

[z]Values reproduced from Ref. 8.

[y]Trace, less than 0.01%.

[x]Not detected under GLC parameters but may be present below 0.001%.

from grapefruit (6, 7) and tangors, e.g., 'Temple' (5).

In contrast to *iso*-branched paraffins where odd-numbered structures predominated, *anteiso*-branched paraffins showed a predominance of even-numbered structures. Of the *anteiso* group, ca. 75% were even-numbered and 25% odd-numbered for the parents ('Clementine', 'Orlando' and 'Minneola'). Among the 5 hybrids, however, these percentages differed markedly. The potential for using the *anteiso* C_{24}/C_{26} ratio to distinguish citrus species was suggested (12, 13). The range for the 5 hybrids was 0.68 ('Osceola') to 1.67 ('Nova'). This broad range prevents these hybrids from being differentiated from oranges (5, 6, 10), lemons (11), grapefruit (6, 7, 9), tangelos (9) and other mandarins (9, 12, 13). Only sour limes with a range of 0.37-0.50 (8) appear to be resolved from these hybrids.

The ratios of linear C_{23} and C_{25} to *iso*-C_{23} and -C_{25} revealed the following interesting comparative data: the linear C_{23}/*iso*-C_{23} ratio for 'Clementine', 3.12, compared favorably with the high mandarin ratios of 2.86 for 'Mediterranean' (13) and 3.50 for 'Dancy' (9). The average 'Duncan' x 'Dancy' tangelo ratio was 0.94 (9). Four of the 5 'Clementine' x tangelo hybrids had ratios within the 1.5-1.9 range (average 1.7) which is near the 2.0 mean of the two parent values. The fifth hybrid ('Osceola') had a high (3.06) C_{23}/*iso*-C_{23} value. Likewise, the C_{25}/*iso*-C_{25} ratios for the 5 hybrids (0.90-1.22) lay between the values of their parents, 'Clementine' (2.08), 'Orlando' (0.61) and 'Minneola' (0.71). These "hybridization values" cannot differentiate these hybrid cultivars from other citrus taxa, however.

Table 3 shows the mono-unsaturated hydrocarbons present in 'Clementine' mandarin, tangelo and hybrid juice sacs. Linear alkenes accounted for 79.8 ('Page') to 93.3% ('Osceola') of the total alkene fraction in the 5 hybrids. From 84.3 to 90.9% of the linear monoenes in the 5 hybrids were odd-numbered. The 5 hybrids differed noticeably in percentages of the 6 major monoenes, i.e., C_{23}, C_{25}, C_{27}, C_{29}, C_{31} and C_{33}. 'Osceola', with high percentages of C_{29} and C_{31}, had a profile similar to those of 'Clementine' and other mandarins (12, 13). 'Nova' had C_{23}, C_{25} and C_{27} percentages similar to those of tangelos, but its C_{31} level (13.6) was ca. 10 x that of 'Orlando', its tangelo parent (1.4). 'Robinson', 'Lee' and 'Page' had linear monoene profiles which clearly differentiated them from each other and from the other two hybrids.

The percentages of total *iso*-branched monoenes were 1.8 for 'Clementine', 17.3 for 'Orlando', 15.0 for 'Minneola' and from 3.6 to 11.9 for the five hybrids. Of this group, odd-numbered monoenes comprised between 84.6 and 90.0% for the 5 hybrids. The 5 hybrids were mandarin-like with respect to their low *iso* C_{23} levels, but their C_{25} percentages varied from 0.8% ('Clementine') to 7.92% ('Orlando'). The two major *iso* monoenes in all parents and offspring were C_{25} and C_{27}.

Anteiso-branched structures in the 5 hybrids comprised between 3.1 ('Osceola') and 11.8% ('Page') of the total monoene fraction. This range extends slightly below the value for 'Clementine' (5.6). For the 5 hybrids the percentage distribution of *anteiso* monoenes was total even-numbered > total odd-numbered, essentially the reverse of that for *iso*-monoenes. This observation has been reported for all citrus examined to date. Even-numbered hydrocarbons ranged from

61.4 ('Robinson') to 76.0% ('Lee'). The 4 major *anteiso* monoenes of the 5 hybrids were C_{24}, C_{26}, C_{27} and C_{28}.

In the previous discussion of Tables 1-3, data were presented which showed that generally the 5 'Clementine' × tangelo hybrids have hydrocarbon profiles intermediate between those of their parents. In some instances the hybrid profiles tended to mirror their mandarin parent rather than their tangelo parent while in others the reverse was evident. These profiles indicate that hybrids subscribe to a "hybridization dilution effect" (13). Further studies are being conducted, based on this observation, in which each of the nine major alkanes (> 79% of total) are correlated with each other. Preliminary results show that the 5 hybrids have a mean "citrus alkane index" value of 35.5 which is in contrast and intermediate between their parents: 'Orlando' (19.9), 'Minneola' (21.0) and 'Clementine' (51.6). The individual hybrid alkane index values, which varied over a 26% range, are being correlated with the hybrid fruits' organoleptic and morphological characteristics. Further studies are being conducted on other hybrids to substantiate the potential usefulness and reliability of this index system in chemically systematizing citrus fruit.

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Salt Tolerance of Some *Citrus* Species, Relatives, and Hybrids Tested as Rootstocks[1]

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Abstract. **Although some selections of the sour orange (*C. aurantium* L.) differed in salt tolerance, none was as salt tolerant as Cleopatra mandarin (*C. reticulata Blanco*). Twenty hybrids were as salt tolerant as Cleopatra and have characters desirable for use in breeding improved rootstocks.**

In most areas where citrus is irrigated with water saline enough for measurable effect on growth and yield, the main salts causing injury are chlorides. Cooper et al. (2) found that the rootstock largely controlled uptake and accumulation of Cl in citrus trees. At salinity levels at which it is feasible to grow citrus, some rootstocks are much more tolerant to chlorides than others because, to a considerable degree, they can exclude Cl. The work of Hewitt et al. (5) indicated that to screen young citrus trees for salt tolerance, the leaves could be analyzed for Cl after 3 or 4 weeks of treatment with highly saline irrigation water. Furr and Ream (3, 4) reported that inheritance of salt tolerance in citrus was quantitative, that most of the progeny from crosses between 2 highly salt-tolerant parents were highly salt tolerant, and that only a few of the progeny of crosses between tolerant and intolerant parents were highly tolerant.

The objective of this work was to screen some species, cultivars, selections, and hybrids of citrus and citrus relatives for salt tolerance and for their potential use in a rootstock breeding program.

Materials and Methods

Clones with valid cultivar names are designated by single quotes, and other names assigned to selections for convenience are without quotes as follows: *C. aurantium* L., 'African', Algerian, Baladi, Bergamia, Bittersweet, 'Brazilian', Ceylon, Cuban, Egyptian, Glenn, Karun Jamir, Keen, Merritt Island, Nansho Daidai, Naranja de Tierra, Olivelands, Palermo, Palestine, Rehoboth, Rhodesia, 'Rubidoux', Sespe, Sicilian, Sicily, Sauvage, 'Standard', Tel Aviv, Tunis; *C. Celebica* Kourd. × *C. grandis* (L.) Osb. (?), 'Alemow'; *C. grandis* (L.) Osb., 'Kao Ruan Tia', Red shaddock; *C. limon* (L.) Burm. f. × (?), 'Karna', Rough lemon; *C. paradisi* Macf., Grapefruit 12509, 'Marsh', 'Redblush'; *C. reticulata* Blanco, 'Changsha', 'Cleopatra', 'Wil-

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