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Chlorine and Other Elements in Avocado Leaves as Influenced by Rootstock[1]

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Chlorine excess is a problem in avocado production in California, in Texas and in Israel (1, 2, 4, 5, 7, 12, 21, and 22). Tipburn of avocado leaves may appear if the Cl in the leaf exceeds 0.25% (2, 7, and 12). Avocado rootstocks influence the elemental composition of scion leaves (5, 6, 7, 13, 14, and 15).

The present field study shows, under commercial conditions, the influence of race and variety of avocado rootstock on the concentration of Cl and other elements in the scion leaves.

MATERIALS AND METHODS

There are 3 general groups of avocados grown in the United States that are loosely termed the West Indian, Guatemalan, and Mexican horticultural races, the last 2 races being of commercial importance in California (20).

From a number of experimental orchards described by Halma (16), 5 in San Diego County, which included Guatemalan and Mexican rootstocks, were selected for this study. Generally, excess Cl problems are greater in San Diego County than in the other avocado growing districts in California. Four of the 5 orchards were planted on various seedling rootstock varieties of both races. Halma (16) describes these seedling rootstock varieties as follows: "...avocados do not come true from seed; hence, in effect, every seedling is a different variety, although some of the progeny may resemble the parent in leaf and fruit characters and growth habit. Therefore, when rootstocks such as Topa Topa or Nabal, for example, are listed as varieties, what is actually meant is that they are seedlings of these varieties. Only progenies obtained by asexual means, such as cuttings, are genetically the same as the parent tree."

In each of the 4 orchards, selections were made for this study so that there were 6 trees of each rootstock-scion combination in a given orchard, arranged in a completely randomized block.

Cuttings of Hass and Fuerte avocado varieties were rooted by E. F. Frolich at the University of California at Los Angeles by the method developed and described by him (11). The Hass cuttings came from 1 tree and the Fuerte cuttings from 2 trees. These

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were planted in orchard No. 5. In the Hass block there were 28 replications comparing the Hass cuttings with Hass trees budded on Mexicola seedlings, the latter having been obtained from a commercial nursery. In the Fuerte block there were 29 replications comparing the Fuerte cuttings with Fuerte trees budded on Mexicola seedlings, the latter also from a commercial nursery. The Hass is of the Guatemalan race while the Fuerte variety is probably a hybrid between the Mexican and Guatemalan races (20). The Mexicola variety is of the Mexican race.

Orchards No. 1, 3, and 5 were planted in 1954 near Fallbrook, No. 2 in 1952 and 1953 in the Pauma Valley, and No. 4 in 1952 near Fallbrook.

During February and March, 1960, 20 of the youngest, fully matured leaves were sampled from each tree from terminals that were not fruiting or flushing. Only the healthiest leaves were sampled, that is, leaves with the least amount of chlorosis and tipburn. This sampling technique tended to minimize the treatment differences observed in this study. The leaves were washed in tap water, rinsed in demineralized water dried in a forced-draft oven at 60° C, and ground in an 8-inch chromium-plated Christy and Norris laboratory mill.

Leaves from all 5 orchards were analyzed for Cl. In addition, leaves from orchards Nos. 4 and 5 were analyzed for N, P, K, Ca, and Mg. Chlorine was determined by the method of Brown and Jackson (3), using a Beckman electrotitrimeter. Methods for determining N, P, K, Ca, and Mg were those used by Embleton *et al.* (10).

The data were analyzed statistically and where applicable were evaluated by the multiple range test of Duncan (8).

RESULTS

Chlorine:—The influence of avocado seedling rootstock variety on the per cent Cl in scion leaves is shown in Tables 1 and 2. Hass and Fuerte scion varieties on Guatemalan rootstocks had substantially less Cl in the leaves than these same varieties on Mexican root-stocks. However, certain individual rootstock varieties within the Guatemalan race showed more Cl in the leaves than did some of the Mexican rootstock varieties. Within the Guatemalan rootstocks, Hass and Nabal generally had relatively low Cl in the scion leaves, and in 3 out of the 4 orchards Anaheim rootstock showed relatively high Cl in the scion leaves. Comparisons among effects of 4 rootstock varieties of the Mexican race that were common to the 4 orchards resulted in the following statistical populations for per cent Cl in scion leaves at the 1% level of probability: Duke, 0.27_{V}; Mexicola, 0.32_{VW}; Ganter, 0.34_{W}; and Topa Topa, 0.36_{W}. Thus, Duke rootstock showed significantly lower Cl in the scion leaves than did Ganter or Topa Topa rootstocks.

At the time of sampling in orchard No. 5, leaves on the Hass trees propagated from cuttings had distinctly less tipburn than leaves on the Hass trees on Mexicola rootstock. Leaves on the Fuerte trees propagated from cuttings generally had less tipburn than leaves on the Fuerte trees on Mexicola rootstock, but the differences were not as distinct as in the Hass. The tipburn appeared to be from excess Cl, and this was confirmed by leaf analysis.

Table 1.—Chlorine concentration in avocado leaves as influenced by rootstock variety and race.

Race and variety of rootstock and statistical indices	Per cent chlorine in dry leaves in indicated orchards[a]			
	Orchard No. 1 Hass scion	Orchard No. 2 Hass scion	Orchard No. 2 Fuerte scion	Orchard No. 3 Fuerte scion
Guatemalan:				
Itzamna	0.12_{v}	—	0.27	0.11_{v}
Sharpless	0.15_{vw}	—	—	—
Taft	0.16_{vw}	0.19_{vw}	0.22	—
Dickinson	0.18_{vwx}	0.22_{vw}	0.19	0.18_{vwx}
Mayapan	0.19_{vwx}	—	—	—
Challenge	0.20_{vwx}	0.15_{v}	0.27	—
Queen	0.24_{wxy}	—	—	—
MacArthur	0.25_{wxy}	0.24_{vw}	0.24	0.16_{vw}
Anaheim	0.25_{wxy}	0.14_{v}	0.25	0.25_{wxy}
Nabal	—	0.15_{v}	0.19	0.08_{v}
Hass	—	0.15_{v}	0.22	0.18_{vwx}
Edranol	—	—	—	0.33_{yz}
Race means	0.19	0.18	0.23	0.18
Mexican:				
Duke	0.23_{wxy}	0.23_{vw}	—	0.28_{xyz}
Blake	0.24_{wxy}	0.30_{vw}	—	—
Mexicola	0.28_{xy}	0.22_{vw}	—	0.35_{yz}
Topa Topa	0.28_{xy}	0.32_{vw}	0.27	0.37_{z}
Northrop	0.29_{xy}	0.38_{w}	—	—
Ganter	0.30_{y}	0.31_{vw}	—	0.34_{yz}
Zutano	—	—	—	0.28_{xyz}
Race means	0.27	0.29	0.27	0.32
Variety significance[b]	**	*	NS	**
Race significance[b]	***	***	—	***
C.V. in %[c]	28	47	57	26

[a]Leaves were sampled in orchard No. 2 in February 1960, and in orchards No. 1 and 3 in March 1960.

Subscript letters v, w, x, y and z after variety means indicate populations within each orchard at the level of probability indicated by the asterisks. Mean values are statistically different if they do not have a common subscript letter after the values.

[b]N.S. indicates that differences between means are not statistically significant.

* indicates significance of F at the 5% level.

** indicates significance of F at the 1% level.

*** indicates significance of F at the 0.1% level.

[c]C.V. in % is the coefficient of variability obtained by dividing the square root of the error variance by the grand mean and multiplying by 100.

Table 2.—Chlorine and other elements in Hass avocado leaves as influenced by rootstock variety, orchard No. 4.

Variety of rootstock & statistical indices	Mean per cent in dry leaves March, 1960[a]					
	Cl	N	P	K	Ca	Mg
			Guatemalan Race			
Hass	0.28_{v}	1.76	0.130_{v}	0.63_{vwx}	1.41_{wx}	0.50_{vw}
Nabal	0.31_{vw}	1.77	0.131_{v}	0.52_{vw}	1.46_{wx}	0.61_{w}
Dickinson	0.35_{vwx}	1.81	0.130_{v}	0.48_{v}	1.59_{x}	0.61_{w}
Anaheim	0.36_{vwx}	1.83	0.136_{vw}	0.53_{vw}	1.41_{wx}	0.62_{w}
			Mexican Race			
Duke	0.32_{vwx}	1.85	0.141_{vw}	0.6[illegible]$_{vwx}$	1.31_{vwx}	0.42_{v}
Ganter	0.42_{wx}	1.90	0.154_{w}	0.66_{wx}	1.05_{v}	0.42_{v}
Blake	0.43_{wx}	1.90	0.153_{vw}	0.66_{wx}	1.18_{vw}	0.48_{v}
Mexicola	0.44_{wx}	1.90	0.152_{vw}	0.60_{vwx}	1.19_{vw}	0.46_{v}
Northrop	0.45_{x}	1.82	0.157_{w}	0.76_{x}	1.00_{v}	0.35_{v}
Topa Topa	0.46_{x}	1.88	0.152_{vw}	0.71_{x}	1.11_{vw}	0.45_{v}
Significance[a]	*	N.S.	**	**	**	**
C.V. in %[a]	27	7	9	16	16	15
Mean Guatemalan race	0.33	1.79	0.131	0.54	1.47	0.58
Mean Mexican race	0.42	1.88	0.151	0.66	1.14	0.43
Significance[a]	***	*	***	***	***	**

[a]See Table 1, footnotes a, b, and c for meaning of statistical symbols.

The Cl in Hass leaves from trees propagated on their own roots (Guatemalan) by cuttings was substantially lower than in Hass leaves from trees budded onto Mexicola (Mexican) rootstock (Table 3).

The same was true in the Fuerte leaves from trees on their own roots (Guatemalan-Mexican hybrid) compared with leaves from trees on Mexicola (Mexican) seedlings but the difference was smaller than in the Hass comparison. Both differences were significant at the 0.1% level.

Table 3.—Comparison of the concentrations of chlorine and other elements in Hass and Fuerte avocado leaves from trees propagated on their own roots by cuttings, with the concentrations in Hass and Fuerte leaves from trees budded on Mexicola seedlings, orchard No. *5*.

Type of root and statistical indices	Mean per cent in dry leaves March, 1960					
	Cl	N	P	K	Ca	Mg
			Hass top			
Hass cutting	0.33	2.01	0.143	0.74	1.23	0.42
Mexicola seedling	0.54	1.98	0.163	0.87	0.98	0.39
Significance[a]	***	N.S.	***	**	***	*
C.V. in %[a]	15	7	10	20	14	14
			Fuerte top			
Fuerte cutting	0.41	1.56	0.130	0.94	1.23	0.49
Mexicola seedling	0.53	1.68	0.135	0.78	1.13	0.52
Significance[a]	***	**	N.S.	***	*	*
C.V. in %[a]	16	7	10	14	13	11

[a]See Table 1, footnotes b and c for meaning of statistical symbols.

Other elements (N, P, K, Ca, Mg):—In orchard No. 4 Guatemalan rootstocks snowed significantly higher P and K and significantly lower Ca and Mg in the Hass scion leaves than did Mexican rootstocks (Table 2). No overlap of effects of rootstock varieties between races for per cent of P, Ca, or Mg in the leaves was observed, nor were there significant differences within races for P, K, Ca, or Mg in the scion leaves.

In orchard No. *5* the Hass trees on Mexicola rootstock had significantly higher P and K, and significantly lower Ca and Mg in the leaves than the Hass trees propagated by cuttings (Table 3). The Fuerte trees on Mexicola rootstock had significantly higher N and Mg and significantly lower K and Ca in the leaves than the Fuerte trees propagated from cuttings.

The experiments in orchard No. *5* were not designed so that effects of Hass and Fuerte scions on Mexicola rootstock could be compared directly. However, the higher N in Hass than in Fuerte leaves on Mexicola rootstocks agrees with observations by Embleton *et al.* (9) that leaves from Hass trees have higher N concentrations than leaves from Fuerte trees growing under similar conditions.

Variability:—Orchard No. 2 contained both Hass and Fuerte scions. Within each scion group, the C.V. in per cent for Cl in the leaves was considerably higher than in other orchards (Tables 1 and 2), thus making statistical evaluation more difficult in orchard No. 2. The terrain in orchard No. 2 was much rougher than in the other orchards; differences due to soil heterogeneity were probably a contributing factor in the high C.V.

In orchard No. 5 the C.V. in per cent for elements in the leaves was similar for the Hass and Fuerte tops (Table 3). For this orchard the C.V. in per cent was determined for each element on a within root type basis; this was done to see if there was less variation in the elements in leaves from trees on clonal roots (cuttings) than in leaves from trees on seedling roots (Table 4). Leaves from trees on seedling roots were more variable in P, K, Ca, and Mg content than leaves from trees on clonal roots. Chlorine was more variable in leaves from trees on clonal roots than on seedling roots. Little difference was found for the variability in N content of the leaves.

Table 4.—Comparison of the variability for the concentrations of elements in Hass and Fuerte avocado leaves from trees propagated on their own roots by cuttings with the variability for the concentrations of elements in Hass and Fuerte leaves budded on Mexicola seedlings, orchard No. 5.

Type of Root	Coefficient of variability in per cent within type of root[a]					
	Cl	N	P	K	Ca	Mg
			Hass top			
Hass cutting	21 ±3.0	8 ±1.1	7 ±0.9	12 ±1.6	8 ±1.0	9 ±1.2
Mexicola seedling	14 ±1.9	6 ±0.7	12 ±1.7	24 ±3.3	22 ±3.1	18 ±2.4
			Fuerte top			
Fuerte cutting	18 ±2.4	8 ±1.1	10 ±1.3	15 ±2.0	13 ±1.7	12 ±1.6
Mexicola seedling	18 ±2.5	10 ±1.3	13 ±1.8	24 ±3.4	18 ±2.4	16 ±2.2

[a]The coefficient of variability was calculated by expressing the standard deviation of the concentration values for a given element within a given root type as a per cent of the mean of the concentration values within a given root type.

DISCUSSION

These studies show that trees on Guatemalan rootstock varieties are generally more tolerant to high Cl conditions than trees on Mexican rootstock varieties. Similar results were reported for the Lower Rio Grande Valley of Texas by Cooper (4, 5), Cooper and Gorton (7), and Cooper, Cowley, and Shull (6); for sand culture experiments in California by Haas (13), and Haas and Brusca (15); and for field observations in Israel by Oppenheimer (21).

This suggests that Guatemalan rootstock should be used in preference to Mexican rootstock where excess Cl is a problem. However, in California it has been shown that Guatemalan rootstocks are generally more susceptible to Verticillium wilt (23), Dothiorella canker (19), and chlorosis, the latter presumably associated with high Ca in the soil (17, 18). Mexican rootstocks will, therefore, probably continue in use in California even though they are more susceptible to Cl excess than Guatemalan rootstocks. In the present studies, there were differences in Cl nutrition attributable to root-stock varieties within the Mexican race. Topa Topa rootstock variety, a common commercial rootstock used in California (20), resulted in higher Cl in the leaves of the scion variety than did other Mexican varieties. Among rootstock varieties of the Mexican race, Duke resulted in the lowest Cl in the leaves.

Zentmyer and Mircetich (24) and Zentmyer and Thorn (25) have found that Duke seedlings and cuttings have appreciable resistance to *Phytophthora cinnamomi,* a very serious disease of avocados in California, while Topa Topa seedlings are very susceptible. Since Duke as a rootstock appears to be more tolerant to excess Cl and shows more resistance to Phytophthora root rot than Topa Topa rootstock, Duke should be considered seriously as a commercial rootstock in California.

West Indian rootstock is rarely used in California primarily because of its lack of cold tolerance. Where it is grown, it has been found to tolerate high Cl conditions more readily than Mexican or Guatemalan rootstocks (5, 14, 21).

SUMMARY

The influence of the race and variety of avocado rootstock on the concentrations of Cl and other elements in scion leaves was studied in 5 commercial orchards in San Diego County where Cl excess is a problem. In the study were 12 varieties of the Guatemalan race, and 7 of the Mexican race. Hass and Fuerte trees propagated on their own roots

were also included.

Guatemalan race of rootstocks showed significantly lower Cl in scion leaves than did Mexican race rootstocks, but there was some overlap of effects of varieties between races.

Within the Mexican race Duke generally showed low and Topa Topa high Cl in scion leaves.

Hass and Fuerte varieties propagated on their own roots by cuttings had significantly less Cl in their leaves than the same scion varieties propagated on Mexicola rootstocks.

Rootstock race and variety influenced significantly the N, P, K, Ca, and Mg in scion leaves.

The per cent of Cl in Hass leaves from trees on seedling root-stocks was less variable than in Hass leaves from trees propagated on their own roots by cuttings. The per cent of P, K, Ca, and Mg in Hass and Fuerte leaves from trees on seedling rootstocks was more variable than in Hass and Fuerte leaves from trees propagated on their own roots by cuttings. Variability of the N in leaves was not appreciably influenced by type of root.

Practical considerations in the selection of rootstocks are discussed.

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