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EFFECTS OF SALINITY ON GROWTH AND PHOTOSYNTHESIS OF 'HASS' AVOCADO ON THREE ROOTSTOCKS.

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Avocado is an important crop worldwide and is often grown in areas where irrigation water is high in soluble salts (Branson and Gustafson 1972). The accumulation of root zone salts has been correlated with reductions in yield (Lahav and Kalmar 1977) and tree volume (Kalmar and Lahav 1977). Avocado rootstocks have traditionally been selected on the basis of their tolerance to *Phytophthora cinnamomi.* Arguably, the second greatest limiting factor to avocado growth and yield is high levels of soluble salts in the soil. Avocado is considered to be very sensitive to high levels of root zone salinity, although relative differences in salt tolerance have been noted among rootstocks (Haas 1950, Embleton *et al.* 1963, Oster and Arpaia 1992). With a limited water supply and low water quality available to avocado growers, these apparent differences have important implications to the avocado industry. Yet, while salt tolerance differences are apparent, the physiological means by which these characteristics express themselves is lacking in the literature.

The effect of avocado rootstocks on the ability of avocado trees to withstand increased levels of salinity in the root zone has been demonstrated by previous experiments, however, the movement of salts through the tree has not been documented to an exact degree. Oster and Arpaia (1992) demonstrated the ability of some avocado rootstocks to sequester Na and Cl in roots, thereby keeping leaf tissue free of potentially toxic levels of these ions.

The objectives of this study were to evaluate the three currently most commercially-important avocado rootstocks and to examine the possible mechanisms of salt tolerance in clonally-propagated material. Further, benchmarks for further salinity trials must be set. This experiment is intended to supply information for further studies of this nature. This study was undertaken as a means of beginning to identify those processes which are most affected by salinity and which might provide an indication of how salt tolerance is achieved in avocado.

One-year-old 'Hass' avocado trees grafted to 'Thomas', 'Toro Canyon', or 'Duke 7' rootstocks were planted in sand tanks at the USDA Salinity Laboratory in Riverside, California on 9 May 1994. Trees were watered four times daily. The base nutrient solution had an electrical conductivity of 1.4 dSm^{1}, and was used as the control, to which NaCl and $CaCl_2$ were added in equal molar amounts beginning on 10 July and increasing levels 1.5 dSm1 per day to reach 3.0 dSm1 on 11 July, 4.5 $dS\ m^{1}$ on 12 July, and 6.0 dSm^{1} on 13 July. Ten trees per salinity level were used for each rootstock to give a total of 120 trees planted in 20 tanks in a split-plot design. All data was subjected to analysis of variance following termination of the project after 65 days. The following measurements were collected over the course of the study: shoot growth rate, trunk cross sectional area, plant vigor and vegetative flushing, leaf necrosis, net CO_2 assimilation and ion uptake.

Increased salinity decreased shoot growth rate in all rootstocks only during the growth flush observed between days 45 and 65 (Figure 1). On day 59, the growth rate of trees exposed to 6.0 dSm^1 salt was 56% that of the control (1.5 dSm^1) trees. 'Duke 7' shoot growth rate was highest during the flush, while 'Thomas' shoots were most affected by increasing salinity. Salinity greatly decreased the cumulative shoot growth of all rootstocks over the course of the study (data not shown). Total shoot growth over the course of the study was least affected in 'Duke 7' trees. Trunk cross-sectional area decreased linearly with increased salinity (Table 1), but was not different between rootstocks.

Leaf necrosis increased with increasing salinity in leaves from flush 1 (Table 2). In flush 1 leaves (fully mature before the initiation of salinity treatments), "Thomas' had the highest percent leaf necrosis and was most severely affected by increased salinity, while 'Toro Canyon' leaves were least affected. Flush 2 leaves (leaves which emerged at the time of initiation of the salinity treatments) did not exhibit necrosis until the 4.5 dS m^1 salt treatment. Flush 3 leaves (leaves that emerged several weeks after initiation of the salinity treatments) did not exhibit necrosis in 'Toro Canyon' or 'Duke 7' leaves, but 'Thomas' leaves from the 6.0 dS m^1 did exhibit necrosis. 'Toro Canyon' had the lowest overall degree of leaf necrosis, while 'Thomas' had the highest.

Vigor and flush ratings decreased with increased salinity in all rootstocks (Table 3). 'Toro Canyon' had the highest vigor ratings with increased salinity, while tree vigor in 'Thomas' trees appeared to be affected to the greatest degree by increased salinity. Shoot flushes in 'Toro Canyon' trees were less affected by increased salinity than were those of the other two rootstocks.

Net CO_2 assimilation was reduced over time only in the 4.5 and 6.0 dSm^{-1} treatments (Figure 6). Rootstock did not have an affect on net CO_2 assimilation. When net CO_2 assimilation was measured for three leaf flushes (day 71-74), assimilation decreased with increased salinity, but no differences between rootstocks existed (Table 5). The degree of reduction in CO_2 assimilation decreased with successive flushes, indicating a possible adjustment to the stress.

'Toro Canyon' sequestered a greater amount of Na and Cl in the roots than did the other two rootstocks (Figures 3 - 6). The Na:K ratio was also lower in 'Toro Canyon' than in the other rootstocks, indicating the ability of this rootstock to utilize K as an osmoticum in adjusting to increased root zone salinity (data not shown). The leaf Na and Cl concentrations of 'Thomas' were much greater than the other rootstocks, particularly with regards to Na. At the 6.0 dSm1 level, 'Toro Canyon' and 'Duke 7' leaves had 0.1 and 13% the Na concentrations of 'Thomas' leaves, respectively.

Leaf necrosis appeared to be related to concentrations of both Na and Cl as 'Thomas' leaves had higher levels of both of these elements than the other rootstocks. It appears that both 'Toro Canyon' and 'Duke 7' leaves adapted to the stress with successive flushes, as is indicated by the lack of necrosis in flush 2 and flush 3 leaves. This is most likely due to a higher concentration of Na and Cl in leaves of 'Thomas', compared to the other rootstocks.

Salinity appeared to affect avocado plants primarily through decreased growth, possibly as a result of a decreased net CO_2 assimilation rate. Although rootstocks did not affect the tolerance of 'Hass' avocado with regards to CO_2 assimilation rate, differences were noted in growth and ion uptake. 'Thomas' responded poorly to elevated salt levels when compared with 'Toro Canyon' and 'Duke 7'. 'Toro Canyon' appeared to adjust to the stress by sequestering Na and Cl in the roots to avoid allowing these ions to accumulate to toxic levels in the leaves. This was reflected in the lower necrotic area and overall greater vigor in 'Toro Canyon' compared to the other two rootstocks.

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Table 1. Trunk cross-sectional area (cm^2) of 'Hass' avocado trees exposed to four salinity levels (n=30) for 10 weeks.

Salinity ($dS \cdot m^{-1}$)	Trunk cross-sectional area (cm^2)
1.5	3.82
3.0	2.78
4.5	1.80
6.0	1.09

Table 2. Percent necrosis of 'Hass' avocado leaves from three flushes on three rootstocks exposed to four salinity levels (n=16) for 10 weeks.

		Salinity ($dS \cdot m^{-1}$)			
Rootstock	Flush	1.5	3.0	4.5	6.0
Thomas	Flush 1	0.18	2.50	18.37	60.55
	Flush 2	0	0	2.13	29.64
	Flush 3	0	0	0	3.24
Toro Canyon	Flush 1	0.14	0.08	5.64	11.17
	Flush 2	0	0	0.13	1.78
	Flush 3	0	0.07	0	0
Duke 7	Flush 1	0.19	0.33	9.66	29.08
	Flush 2	0	0	5.26	12.70
	Flush 3	0	0	0	0

Table 3. Ratings of vigor and flush of 'Hass' avocado trees on three rootstocks exposed to four salinity levels (n=10) for 10 weeks.

		Salinity ($dS \cdot m^{-1}$)				
	Rootstock	1.5	3.0	4.5	6.0	*RS mean*[z]
Vigor	Thomas	7.8	6.2	4.6	2.8	*5.4*
	Toro Canyon	7.0	7.1	6.2	4.3	*6.2*
	Duke 7	7.0	7.2	5.6	3.4	*5.8*
	Salt mean	*7.3*	*6.8*	*5.5*	*3.5*	
Flush	Thomas	7.8	6.9	5.2	4.1	*6.0*
	Toro Canyon	7.0	7.9	6.2	5.4	*6.4*
	Duke 7	7.7	7.9	6.4	4.5	*6.6*
	Salt mean	*7.5*	*7.2*	*5.9*	*4.7*	

[z] RS = rootstock

Tree vigor and vegetative flushing rated on a 1 to 10 scale where 10 is equal to vigorous growth and 1 is equal to no growth.

Table 4. Net photosynthetic rate ($\mu mol \cdot cm^{-2} \cdot s^{-1}$) of three flushes of 'Hass' avocado leaves on three rootstocks exposed to four salinity levels for 10 weeks.

		Salinity ($dS \cdot m^{-1}$)			
Rootstock	Flush	1.5	3.0	4.5	6.0
Thomas	Flush 1	4.35	2.30	1.75	0.14
	Flush 2	6.84	4.28	3.20	1.82
	Flush 3	5.47	4.18	3.20	3.38
Toro Canyon	Flush 1	4.31	2.19	3.36	0.98
	Flush 2	6.42	6.00	6.16	2.69
	Flush 3	4.95	3.62	3.70	2.58
Duke 7	Flush 1	5.25	1.88	0.91	0.92
	Flush 2	7.31	5.79	2.71	2.33
	Flush 3	6.01	6.02	3.81	3.20

Figure 1. Shoot growth rate (mm/day) as influenced by salinity treatment.

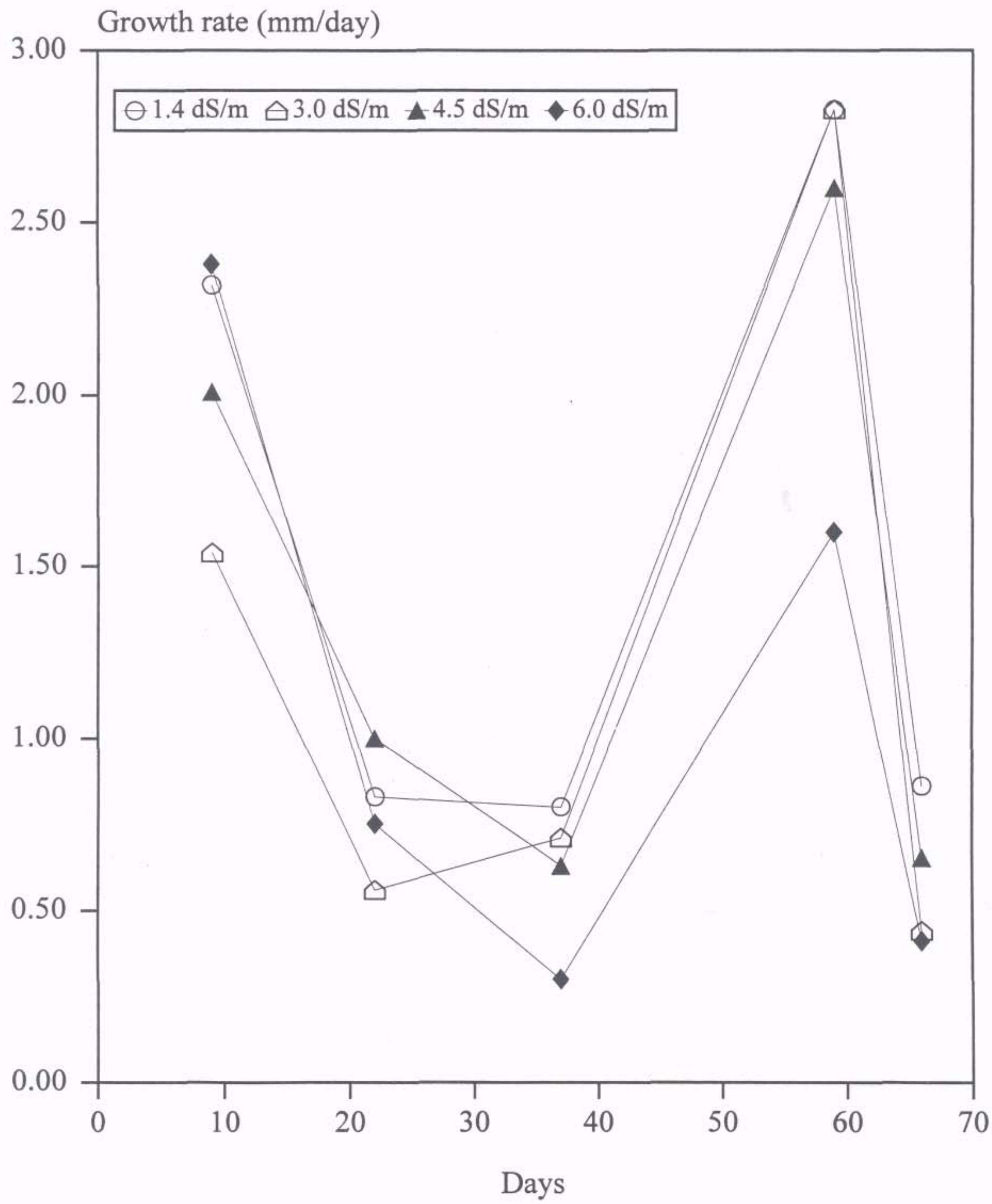

Figure 2. Net carbon dioxide assimilation as measured as a percentage of the control treatment (1.5 dS/m).

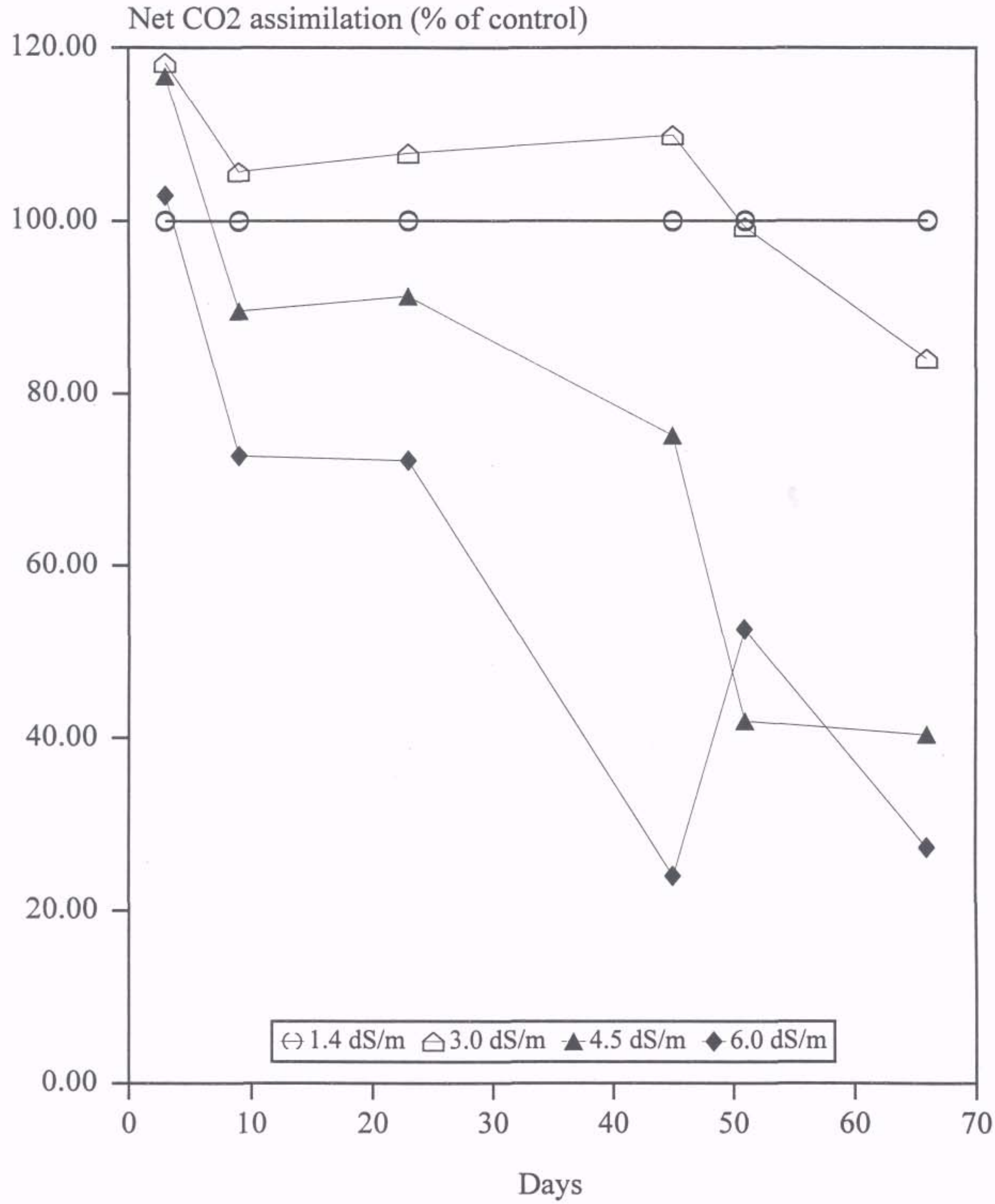

Figure 3. Sodium concentration in the **stems, trunk and roots** of 'Hass' on clonal rootstocks in response to differential salinity treatments.

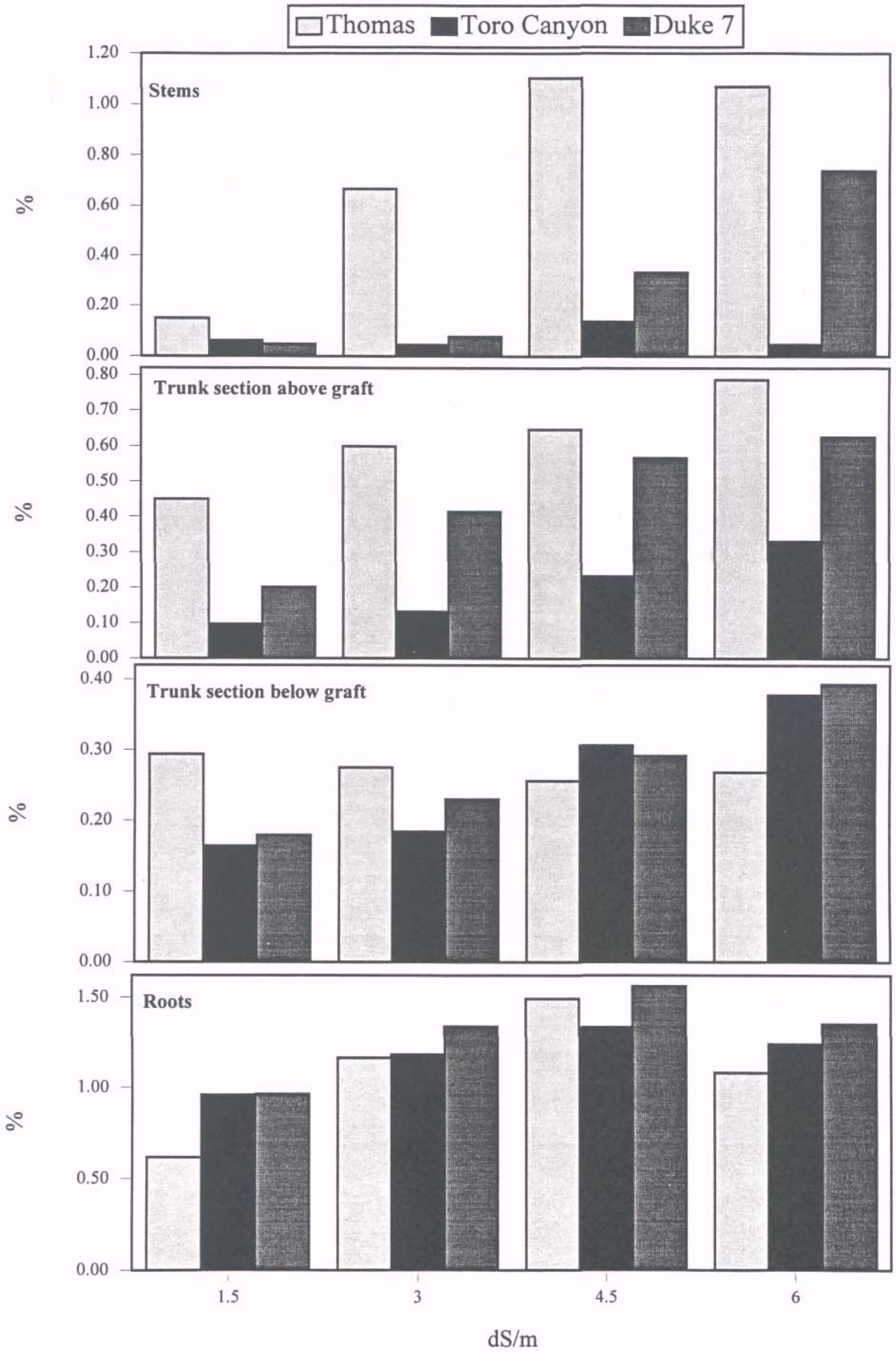

Figure 4. Sodium concentration in **foliage** of 'Hass' on clonal rootstocks in response to differential salinity treatments.

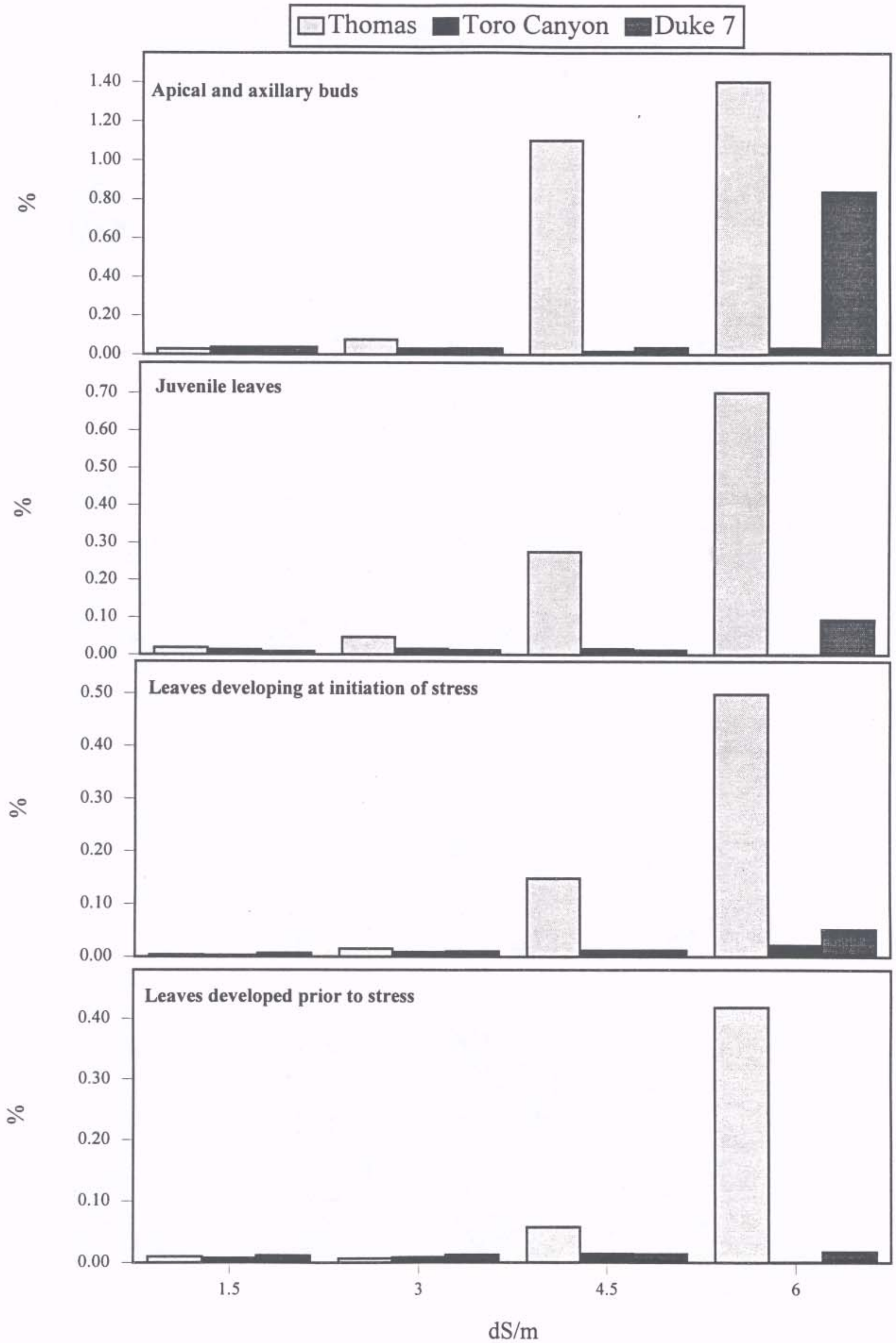

Figure 5. Chloride concentration in the **stems, trunk and roots** of 'Hass' on clonal rootstocks in response to differential salinity treatments.

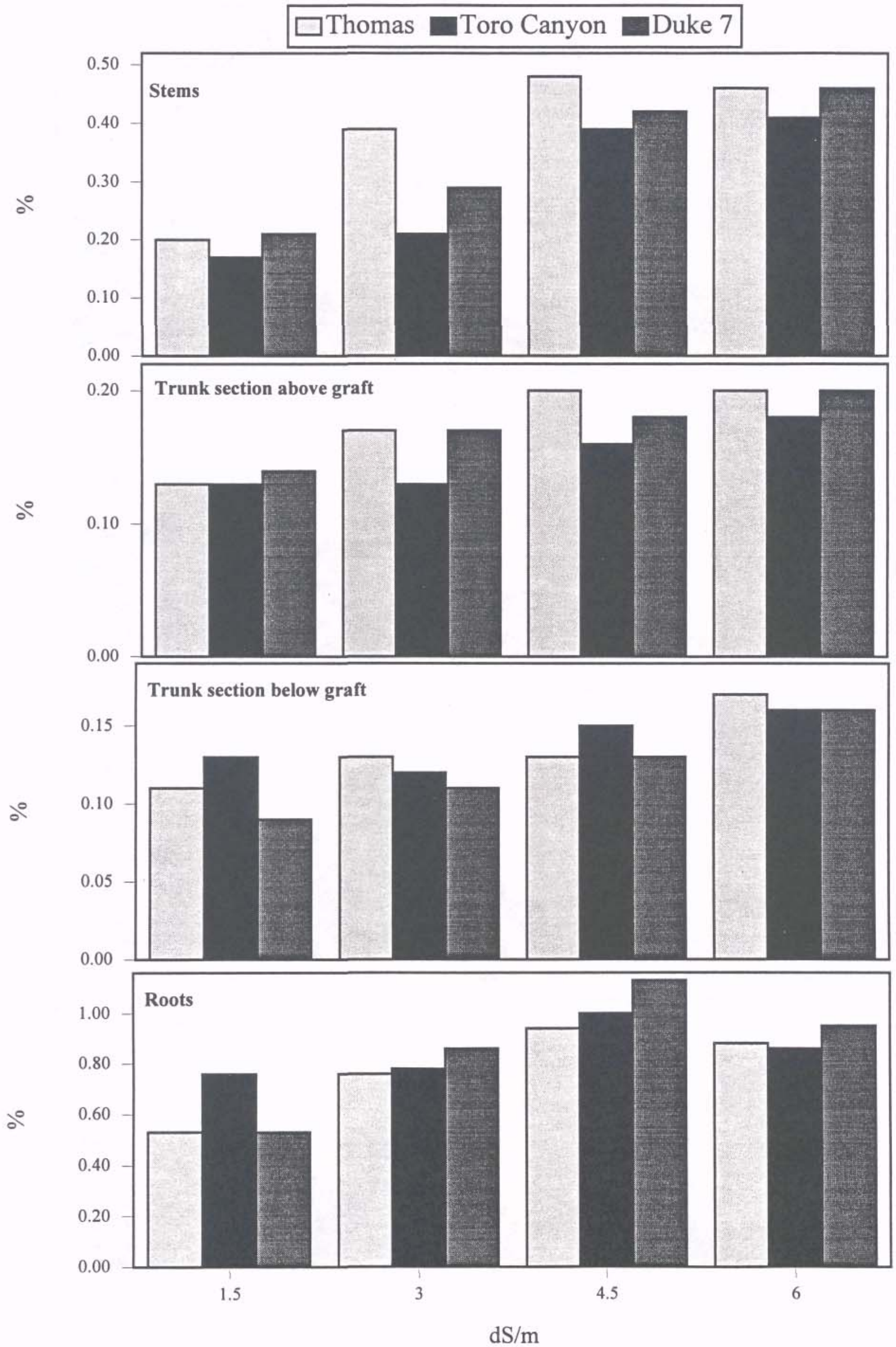

Figure 6. Chloride concentration in **foliage** of 'Hass' on clonal rootstocks in response to differential salinity treatments.