Proceedings of the First International Tropical Fruit Short Course: The Avocado.
J.W. Sauls, R.L. Phillips and L.K. Jackson (eds.). Gainesville: Fruit Crops Dept., Florida Cooperative Extension Service. Institute of Food and Agricultural Sciences, University of Florida, 1976. Pages 58-60.

GROWING AVOCADOS IN AREAS OF HIGH SALINITY

Shmuel Gazit[1] and Amnon Kadman[2]

When avocados are grown in arid or semi-arid climates, irrigation is necessary. Salinity damage is apt to ensue if the water contains appreciable amounts of salt, especially sodium (Na^+) and chloride (Cl^-) salts. Salt damage occurs in California (7, 8, 12), Texas (9, 10, 14), western and southern Australia, Israel (2, 21, 22) and probably many other places as well. About 20 years ago, salinity was considered to be the number one problem of the then infant avocado industry of Israel (21). The problem was caused by rising Cl^- levels in many wells along the coastal plain (the main avocado-growing region at that time) and the "doomsday" knowledge that the National Water Carrier would begin in a few years to supply most of the actual and potential avocado-growing areas with water that was considered to be too saline (170-250 mg Cl/l) for successful avocado production. Now, 20 years later, the area planted with avocados in Israel is 10 times as large and salinity is not considered a significant problem, which testifies to the fact that a successful, practical solution can be found. The use of new rootstocks and drastic changes in irrigation practices were factors responsible for this success. The less severe salinity problem in California has also been solved, mainly by improvements in irrigation practices (12, 13).

Susceptibility of the 3 Avocado Races

It has been frequently stated that the avocado tree is very sensitive to saline conditions (5, 6, 8, 19), being considered the least tolerant tree crop to soil salinity (8). These statements are correct only when dealing with plants belonging to, or grafted on, Mexican race *(Persea americana* var. *drymifolia)* avocados. It has been repeatedly demonstrated on the other hand that Guatemalan race *(P. americana* var. *guatemalensis)* plants are significantly more-tolerant to salinity and West Indians *(P. americana* var. *americana)* can be considered as salinity-tolerant plants (2, 3, 4, 17, 18, 19, 20, 21). The variability within each race and ready hybridization between races may cause variability in salinity tolerance between races (2, 19, 20, 23).

Chemical Components Responsible for the Salinity Effect

Chloride and Na^+ are usually the ions responsible for salinity damages in avocado and a direct correlation was found between their content in plant tissue and severity of salinity symptoms exhibited in a genetically uniform population (1, 6, 7, 15). The 3 races differ in their ability to resist uptake of these toxic elements (15, 20), in their ability to retain these elements in the root systems without releasing them into the upper part of the

[1]Horticulturist, Faculty of Agriculture, Hebrew University, Rehovot, Israel.
[2]Horticulturist, Agricultural Research Organization, Volcani Center, Bet Dagan, Israel.

plant (17, 18, 20) and in their tolerance of these elements in their tissues (17, 18, 19, 20). There is a pronounced difference between the 2 elements in excess symptoms and mode of translocation.

Chloride

The symptoms of Cl^- excess are: marginal and tip burn which spreads inward toward the midrib of the mature leaf. Eventually the severely damaged leaves drop prematurely (1, 6, 9, 14, 15). The Cl^- moves up in the transpiration stream and accumulates in the affected areas of the scorched leaf (17, 20). Slight symptoms of tipburn occur in Mexican and Guatemalan plants when leaf Cl^- content exceeds 0.4% (in dry matter); leaves afflicted with medium tipburn have 0.5-0.75% Cl^-. Values above 1.0% indicate severe cases of tipburn caused by Cl^- toxicity (1,6, 11, 14, 15). West Indian leaves are somewhat more tolerant to Cl^- (20) and 'Glickson 7' leaves exhibited rather high tolerance to Cl^- though this variety is identified as a Mexican (17).

Sodium

Sodium excess symptoms appear as circular necrotic spots scattered between the leaf veins (1, 16). All 3 races tend to keep the Na^+ within the root systems and only in extreme cases does it move up (1, 15, 16, 18. 23). Sodium content in the leaf is usually quite low less than 0.1%, (in dry matter). Contents above 0.4% indicate Na^+ injury. Values of 0.6-1.0% occur in severe cases of Na excess (7).

Salinity Causes

Apart from the rare instances where the soil was originally saline, irrigation water is the main source and cause of salinity. Water with 150 ppm NaCl, considered suitable even for the Mexican avocado, will contribute in one year with a yearly application rate of 10,000 m /ha, the enormous amount of 1.5 m. ton of NaCl/ha. Rainfall may leach this salt out of the root zone (the upper 60 cm at least) but if natural rainfall will not suffice, it is imperative to apply excess water so that adequate leaching will occur. Even a temporary rise in the soluble Cl^- concentration in the soil may cause considerable tipburn (6, 8, 17). Use of fertilizers containing Cl^- or Na^+ and saline manure (especially chicken manure) may aggravate a salinity problem.

Water and Soil Criteria

Water quality is the dominant factor for both Cl^- and Na^+. Irrigation can easily change the content of these elements in the soil with one basic exception: we cannot decrease soil salinity below that of the irrigation water.

Chloride

This is the element responsible for the large majority of salinity in orchards. In Israel, water suitability for commercial avocados is graded as follows: 120-150 mg/l for Mexican rootstocks, 200-250 mg/l for Guatemalan rootstocks and 350 mg/l for West Indian rootstocks. Experimental plots grafted on the right rootstock (2, 3) are growing successfully even when irrigated with water containing 500 mg/l Cl^-. The upper limit for trees grafted on Mexican rootstocks in California was reported to be 125 mg/l. Values in excess of 5 meq/l (about 165 mg/l) in the soil saturation extract are considered as the upper limit for Mexican rootstocks (5, 8).

Sodium

The interaction between Na^+ and divalent ions, especially on soil and plant injury (7, 8, 16), brought into general use the value of the Sodium Absorption Ratio (in meq/l). SAR values in excess of 4 are considered hazardous (7), while severe leaf burn develops when values are about 6 (8). These values are relevant for Mexican rootstocks that are in use in California. West Indian rootstocks apparently enable the plant to tolerate higher values (18, 20) but no definite criteria have been established.

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Rootstocks for Growing Avocado in Areas of High Salinity

Acclimatization plots of various subtropical fruit trees were planted in many different locations in Israel (then Palestine) about 40 years ago. It was established that plants belonging to the West Indian race were highly resistant to saline (200 mg/l Cl^-) irrigation water and were far superior to Mexican types. It was also established that Mexican and Guatemalan varieties budded on West Indian stocks grew successfully under these conditions (22). Similar conclusions were reached in Texas (10, 24).

A program of controlled selection of Mexican, Guatemalan and West Indian types that excel in their tolerance of salinity has been conducted in Israel for the last 20 years (2, 3, 18, 19, 20). Two approaches have been used side by side: 1) selection of types that gave a resistant seedling population (2, 3) and 2) selection of individual resistant plants for vegetative propagation.

Use of Seedling Populations

The avocado tree is notoriously extremely heterozygous, especially when pollination is not controlled. Nevertheless, many types gave populations that were quite uniform as far as salinity tolerance is concerned. At first, practical experience and a later systematic survey (2) enabled selection of types that have a tolerant seedling population. More than 300 different West Indian varieties and types have been in use (3). Those that give the best results are propagated and planted in special plots to assure suitable pollination.

All commercial orchards have been planted with these seedling rootstocks and when a shortcoming is discovered in a certain population, it is taken off the list recommended for use (2).

The large group named in Israel as West Indian include; many hybrids with Guatemalan and probably also Mexican types. The subgroup excelling in salinity tolerance is called the "Pure" or "Hard" West Indian. It includes mainly the 'Nahlat' types and their descendants ('Maoz' is probably one of them).

Vegetative Propagation

This approach gave us a few uniform Mexican, Guatemalan and West Indian hybrids. Unfortunately, the closer we come to the genuine West Indian and to high salinity tolerance, the more difficult it is to obtain rooted cuttings. 'Fuchs 20' gave the best results of the 6 selections tested as rootstocks for 'Hass' and 'Fuerte' with irrigation water of 350 mg/l Cl^-. It is followed by 'Anaheim 3', 'Lula 3' 'Benik 31/6' and 'Gvaram 13'. Trees grafted on the least tolerant of these selections grew and fruited well. Control trees grafted on a sensitive Mexican rootstock, 'Northrop 98/5', have degenerated and most of them died. The commercial use of these stocks is still hampered by the great difficulty and high cost of the rooting and grafting phase.

Rootstock-Scion Interaction

Tolerance to salinity rests with the rootstock. If a resistant West Indian scion is grafted on a sensitive Mexican rootstock under saline conditions it will show injury symptoms like a Mexican type (20). Nevertheless, there is some effect of the scion, as can be seen in Table 1 (19, 20).

Table 1. Leaf burn in avocado plants at the end of a second year of a salinity trial.

	Leaf burn readings[z]		
		Grafted with:	
Rootstock[y]	Non-grafted	Fuerte	Nabal
‘Mexicola’	3.7	3.0	2.7
‘Nabal’	2.5	1.9	1.7
West Indian	1.0	1.8	1.4

[z] 0 = no burn, 5 = very severe burn.
[y] Means of 24 plants.

Source: Kadman and Ben-Ya’acov (20).

Summary

There is a great difference between the salinity tolerance of the 3 avocado races—the Mexican types being very sensitive while the West Indian types show a high tolerance and Guatemalan show medium tolerance.

Injury under saline conditions is usually by Cl^- toxicity. The Cl^- moves up in the transpiration stream, accumulates in the distal leaf tissue, and causes the prevalent tip-burn and margin burn. Excess Cl^- symptoms appear when the leaf Cl^- content exceeds 0.4% of dry matter. Severe burn occurs with values of 1.0% and above.

Sodium toxicity is much less prevalent. Sodium tends to be retained by the root system and usually its content in the leaf tissue is below 0.1% (of dry matter). When Na^+ content in the leaves exceeds 0.4%, injury symptoms appear as circular necrotic spots.

Usually the main source and cause of salinity are saline irrigation water and faulty irrigation program. The Cl^- content of the water is the dominant factor responsible for salinity damages. The upper recommended Cl^- values in the irrigation water are as follows: 120-150 mg/l for Mexican stocks, 200-250 for Guatemalan stocks and 350-500 for West Indian stocks.

The use of selected West Indian types enabled commercial planting with irrigation water containing up to 350 mg/l Cl^-.

Sodium damage occurs when the SAR value of the irrigation water is 4.

The use of tolerant rootstocks with the right irrigation practices enables growing avocados in areas of high salinity.

Literature Cited

1. Ayers, A. D., D. G. Aldrich and J. J. Coony. 1951. Sodium and chloride injury of 'Fuerte' avocado leaves. *Calif. Avoc. Soc. Yrbk.* 36:174-178.
2. Ben-Ya'acov, A. 1972. Avocado rootstock - scion relationship: A long-range large-scale field research project. *Calif. Avoc. Soc. Yrbk.* 55:158-161.
3. _________. 1976. Avocado rootstocks in use in Israel. *Calif. Avoc. Soc. Yrbk.* 59:66-68.
4. Bergh, B. O. 1975. Avocado. in Advances in fruit breeding, J. Janick and J. N. Moore, eds. Purdue Univ. Press, West Lafayette, IN. p.541-567.
5. Bernstein, L. 1965. Salt tolerance of fruit crops. U.S.D.A. Agr. Info. Bui. 292.
6. Bingham, F. T. and L. B. Fenn. 1966. Chloride injury to 'Hass' avocado trees: A sand culture experiment. *Calif. Avoc. Soc. Yrbk.* 50:99-106.
7. _________ and C. O. Nelson. 1971. The effects of sodium on mature avocado trees. *Calif. Avoc. Soc. Yrbk.* 54:75-78.
8. Branson, R. L. and C. D. Gustafson. 1972. Irrigation water a major salt contributor to avocado orchards. *Calif. Avoc. Soc. Yrbk.* 55:56-60.
9. Cooper, E. C. 1948. Tipburn problem in avocados. *Texas Avoc. Soc. Yrbk.* 32:52-53.
10. _________. 1951. Salt tolerance of avocados on various rootstocks. *Texas Avoc. Soc. Yrbk.* 35:24-28.
11. Embleton, T. W., M. Matsumura, W. B. Storey and M. J. Garber. 1961. Chloride and avocado rootstocks. *Calif. Avoc. Soc.Yrbk.*45:110-115.
12. Gustafson, C. D. 1962. The salinity problem in growing avocados. *Calif. Avoc. Soc. Yrbk.* 46:100-105.
13. _________, A. W. Marsh, R. S. Branson and S. Davis. 1973. Drip irrigation experiments with avocados in San Diego County. *Calif. Avoc. Soc. Yrbk.* 56:109-112.
14. Hass, A. R. C. 1929. Composition of avocado trees in relation to chlorosis and

tipburn. *Bot. Gaz.* 87:422-430.

15. _________. 1950. Effect of sodium chloride on Mexican, Guatemalan and West Indian avocado seedlings. *Calif. Avoc. Soc. Yrbk.* 35:153-160.

16. _________. 1950. Calcium in relation to the effects of sodium in avocado seedlings. *Calif. Avoc. Soc. Yrbk.* 35:161-168. 17.

17. Kadman, A. 1963. The uptake and accumulation of chloride in avocado leaves and the tolerance of avocado seedlings under saline conditions. *Proc. Amer. Soc. Hort. Sci.* 83:280-286.

18. _________. 1964. The uptake and accumulation of sodium in avocado seedlings. *Proc. Amer. Soc. Hort. Sci.* 85:179-182.19.

19. _________. 1968. Selection of avocado rootstocks suitable for use with saline irrigation water. *Calif. Avoc. Soc. Yrbk.* 57:145-147.

20. _________ and A. Ben-Ya'acov. 1970. Avocado: Selection of rootstocks and other work related to salinity and lime, *in* The Division of Subtropical Horticulture 1960-1969, Volcani Inst. Agr. Res., Bet Dagan, Israel, p.23-40.

21. _________ and _________. 1976. Selection of avocado rootstocks for saline conditions. *Acta. Hort* (In press).

22. Oppenheimer, C. 1947. The acclimatization of new subtropical fruit trees in Palestine. Agr. Res. Sta., Rehovot, Palestine, Hul.44.

23. Patel, P. M., A. Wallace and R. T. Mueller. 1976. Salt tolerance of 'Huntalas' compared with other avocado rootstocks. *Calif. Avoc. Soc. Yrbk.* 59:78-85.

24. Randle, J. H. 1949. Future avocado rootstock problems. *Texas Avoc. Soc. Yrbk.* 33:49-50.