Rootstock Selections for Improved Salinity Tolerance of Avocado

Continuing Project; Year 4 of 6

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Benefit to the Industry

Avocado trees are susceptible to salinity. Symptoms include leaf scorch and decreased tree productivity. As the cost for irrigation water continues to increase, and growers increasingly rely on saline groundwater supplies, there has been an increasing need to identify salt tolerant rootstocks that may be used for saline soils. This research is aimed at evaluating recently introduced salt tolerant rootstocks for use with 'Hass' avocado, and is also comparing these new rootstocks with the commercial and newly developed rootstock materials from the UCR rootstock breeding program.

Objectives

1. To compare the salinity tolerance of currently used and newly developed Phytophthora root rot resistant rootstocks in a screening system, which will allow us to recommend specific rootstocks that can be used by avocado growers in California.
2. Identify new rootstocks that might be incorporated into the ongoing breeding program at UCR for selection of Phytophthora resistant, salinity tolerant plant material.

Introduction

Avocado trees are susceptible to salt damage, but are frequently grown in areas where irrigation water contains high levels of sodium chloride. Resulting problems associated with high soil salinity and chloride toxicity include reductions in fruit yield and tree size, lowered leaf chlorophyll content, decreased photosynthesis, poor root growth, and leaf scorching. In California, this problem has becoming increasingly common as the cost for high quality irrigation water has increased and growers leach their soil less frequently, or are forced to rely on saline groundwater for their irrigation water supply. Another factor that further contributes to salinity problems is the use of mulch and other soil organic matter amendments that are used to improve soil fertility and disease management, but which release salts as they decompose. Lastly, root damage and increased leakage of root exudates from salt affected roots is speculated to cause increased susceptibility to *Phytophthora* root rot.

Although there are only a few California-derived rootstocks that have been directly compared for salinity tolerance to date (Micklebart and Arpaia, 200_), field observations have suggested that salt tolerance is greatest in West Indian rootstocks and poorest in the Mexican rootstock cultivars (Embleton, et al., 1955; Ben-Ya'acov, 1970; Gustafson et al., 1970). In southern California, West Indian rootstocks have not been used in rootstock selection programs. However, several West Indian varieties have been identified as salinity tolerant. With further testing, some of these West Indian rootstocks may prove to be useful for saline soils, or may be incorporated into the avocado rootstock breeding program. The data of Mickelbart and Arpaia (200_) and Oster and Arpaia (1991) suggest that there is also considerable variation in salt tolerance among Mexican and Mexican-Guatemalan rootstocks, which might be useful for avocado production on saline soils.

Physiological mechanisms of salt tolerance include a number of responses that have been characterized in various model plants. One effect of high sodium is the displacement of calcium from the root cell walls, which causes leakage of potassium and other plant metabolites (Spiegel et al., 1987). As reviewed by Kafkafi and Bernstein (1997), maintenance of adequate potassium concentrations and the proper potassium/sodium ratios is necessary for cellular function under saline conditions. This idea is further supported in experiments with mung bean in which calcium additions were shown to reverse the inhibition of root elongation by NaCl and to maintain high potassium levels in the roots (Nakamura et al., 1990). In lime trees, resistance to salinity is associated with chloride exclusion and high selectivity of the roots for potassium as opposed to sodium (Storey and Walker, 1987). These data suggest that maintenance of high potassium and calcium concentrations in the rooting zone may help to offset the effects of salinity.

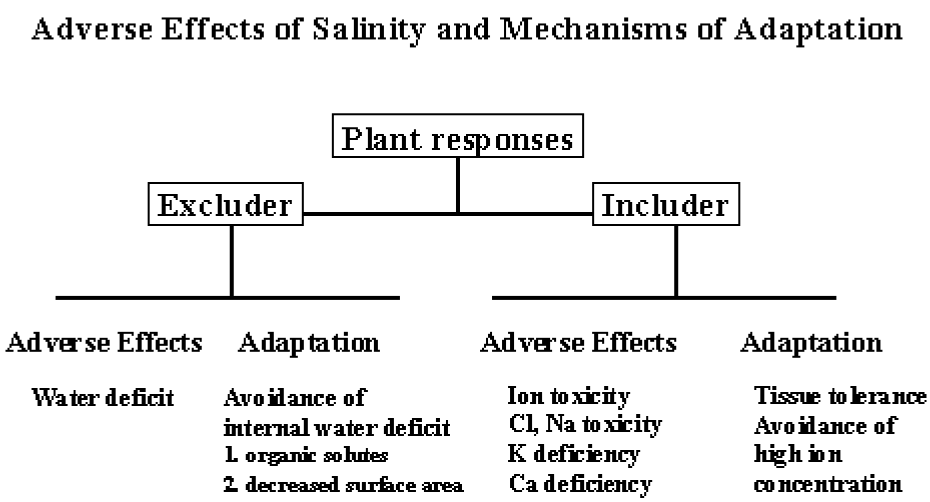

Figure 1. Model showing the classification of trees as excluder or includer species and the specific adaptations that occur with respect to these different strategies.

Several general mechanisms for salinity tolerance are summarized in Figure 1 (adpated after Marschner 1996). According to the manner in which salinity tolerant rootstocks adapt, rootstocks may be classified as either salt "excluder" or "includer" types. For grafted trees, another consideration is whether or not sodium or chloride are transported to the leaves. If they are retained in the root tissue of an includer species, then it is also important to examine accumulation and possible toxcity effects on root growth as well as the effects of impaired root growth on performance of the scion. Thus, studies on the salt tolerance of grafted trees are more complex than simply examining leaf tissue contents of sodium and chloride.

Materials and Methods

In our research we are examining rootstocks for their relative salinity tolerance. This involves both field studies that are being initiated this year, and greenhouse experiments that have been ongoing for the past two years. All of these experiments are using 'Hass' avocado that has been grafted on to selected rootstocks from Israel or that have shown promise in the avocado root rot screening program. The hydroponic screening system in the greenhouse study consists of 120 5-gallon containers that are hooked in line into a re-circulating irrigation system that automatically delivers nutrient solution and salt treatments to the trees 4 times a day. The nutrient solution consists of a modified Hoagland's nutrient solution, and contains carefully controlled trace metal concentrations employed a chelator buffered system. There are 12 replicate trees per treatment, with Duke 7 grafted trees included as a control in each experiment. The salinity treatments are designed to mimic typical irrigation water in Southern California, as described in the USDA handbook (USDA 1954; see also http://www.ussl.ars.usda.gov/hb60/hb60.htm), but are lower in carbonate, which interferes which pH control and trace metal availability. The principal cations are calcium, sodium, magnesium, and potassium. The anions include sulfate, nitrate, and chloride. Calcium and sodium are adjusted along with chloride and sulfate to provide different levels of chloride. Total salinity is maintained at a constant value of 3 dS/M (TDS 2000 ppm) with chloride adjusted to 2, 4, 8, and 16 meq/L. If we identify rootstocks that are particularly resistant to the effects of high chloride, we will increase the salt levels to an appropriate level that will test the full extent of salt tolerance of these more tolerant selections. Parameters being measured include shoot and root growth, trunk diameter, and tissue contents of Na, Cl, K, Ca, and metals.

Results and Discussion

Leaf tissue analysis for chloride accumulation in 'Hass' grafted to the first 3 rootstocks tested in 1999 are shown in Fig. 2. These data show that there are significant differences in chloride accumulation by 'Hass' grafted on to VC 239 and VC 241 as compared to Duke 7 when grown at intermediate levels of chloride at 4 and 8 meq /L. Decreased chloride accumulation was also observed for VC 239 at 16 meq/L; whereas, VC 241 was not different from Duke 7 at this high concentration. In brief, these data show that neither of the two rootstocks tested were salt tolerant as compared to recent studies with VC 256 and VC 209 tested in 2000 (reported below).

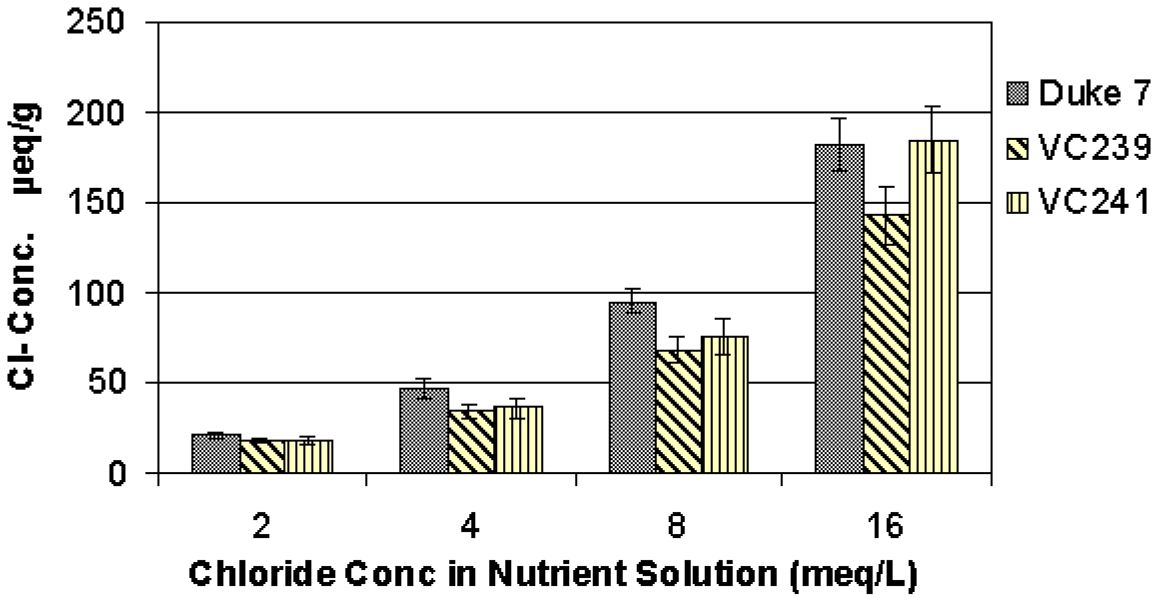

Figure 2. Leaf tissue chloride contents of trees sampled in September 1999 for trees grown in hydroponic sand cultures in the greenhouse.

A similar pattern was observed for leaves from these same trees that were sampled in June 2000 (data not shown). For these three rootstocks, there were virtually no differences in chloride accumulation at the different salt levels. Analysis of leaf tissue contents of sodium and metals for leaves sampled in September 1999 and June 2000 showed scions grafted on VC239 contained significantly higher levels of sodium than trees grafted on either Duke 7 or VC 241 (Figure 3). The decline in sodium content at increasing levels of chloride corresponds to an increase in the calcium:sodium ratio of the nutrient solutions with each step increase in chloride content. These data suggest a strong calcium-sodium interaction for this particular rootstock.

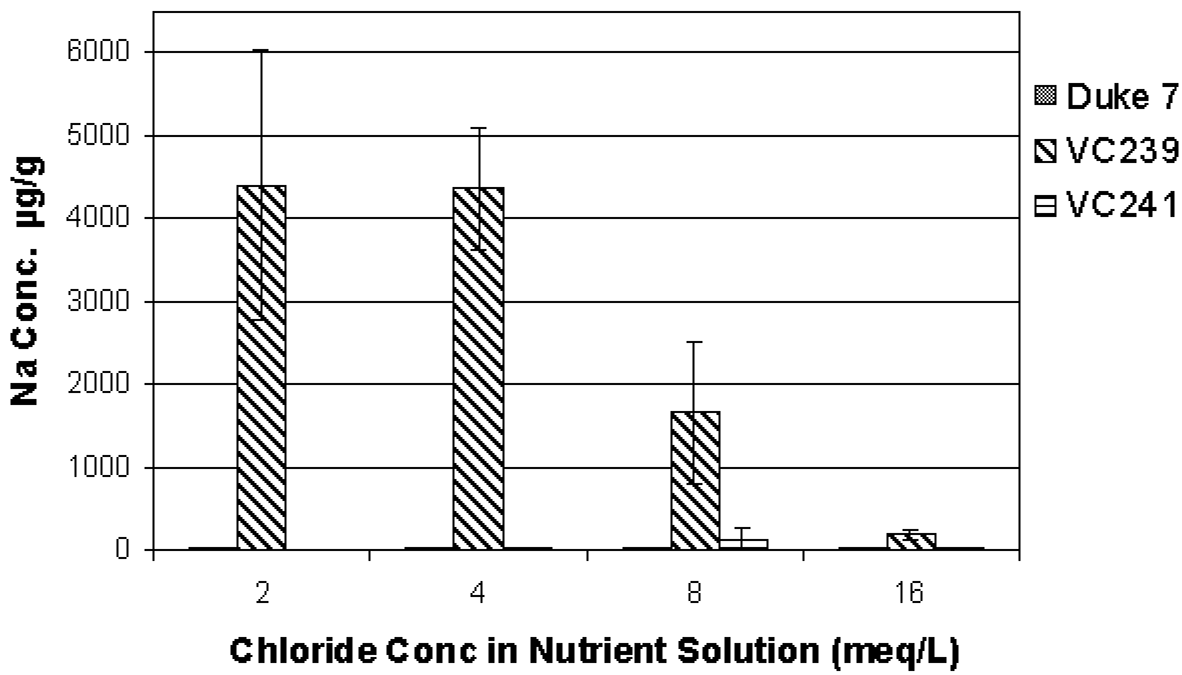

Figure 3. Leaf tissue sodium concentration of leaves from 'Hass' scions grafted on to three different rootstocks for trees grown in hydroponic sand cultures in the greenhouse at 4 chloride levels. In this hydroponic system, the Ca:Na ratios increased at step increase in chloride, which may explain the decline in Na content for VC 239, which was otherwise a sodium accumulator.

The second experiment conducted this year compared two other West Indian rootstocks, VC 207 and VC 256 with Duke 7. In this experiment, only two chloride concentrations, 2 and 8 meq/L were used for the screening. Interestingly, in this experiment, both of the West Indian rootstocks proved to be highly superior for excluding chloride from the scion as compared to Duke 7 (Figure 4A). At 2 meq/L, all of the leaves of 'Hass' had similar Cl levels; whereas, at 8 meq/L Cl, trees grafted on Duke 7 took up 100 mg/kg Cl. In comparison, trees grafted on VC 207 and VC 256 took up 20 and 40 mg/kg Cl, respectively. The value for Duke 7 compares well with the prior experiment and shows the reproducibility of the hydroponic screening system from one experiment to the next. Analysis of the root tissue for trees harvested at this time showed that relatively large amounts of chloride accumulated in the root tissue of all three rootstocks as compared to the leaves (Figure 4B). At 8 meq/L, both VC 207 and VC 256 accumulated significantly greater amounts of chloride than Duke 7. These results suggest that both of the West Indian rootstocks may be classified as "includers", which take up chloride, but which did not translocate chloride to the shoot. Analysis of the shoot:root ratios (data not shown) suggest that there were no harmful effects of chloride on the roots, although the field performance still needs to be evaluated.

Analysis of other nutrients and metals showed there were no significant differences in uptake of zinc and iron, but the effects of manipulating potassium and calcium to further increase salt tolerance remained to be tested. This will be studied once the most promising candidate rootstocks have been identified for more intensive study over a broader range of chloride and sodium concentrations.

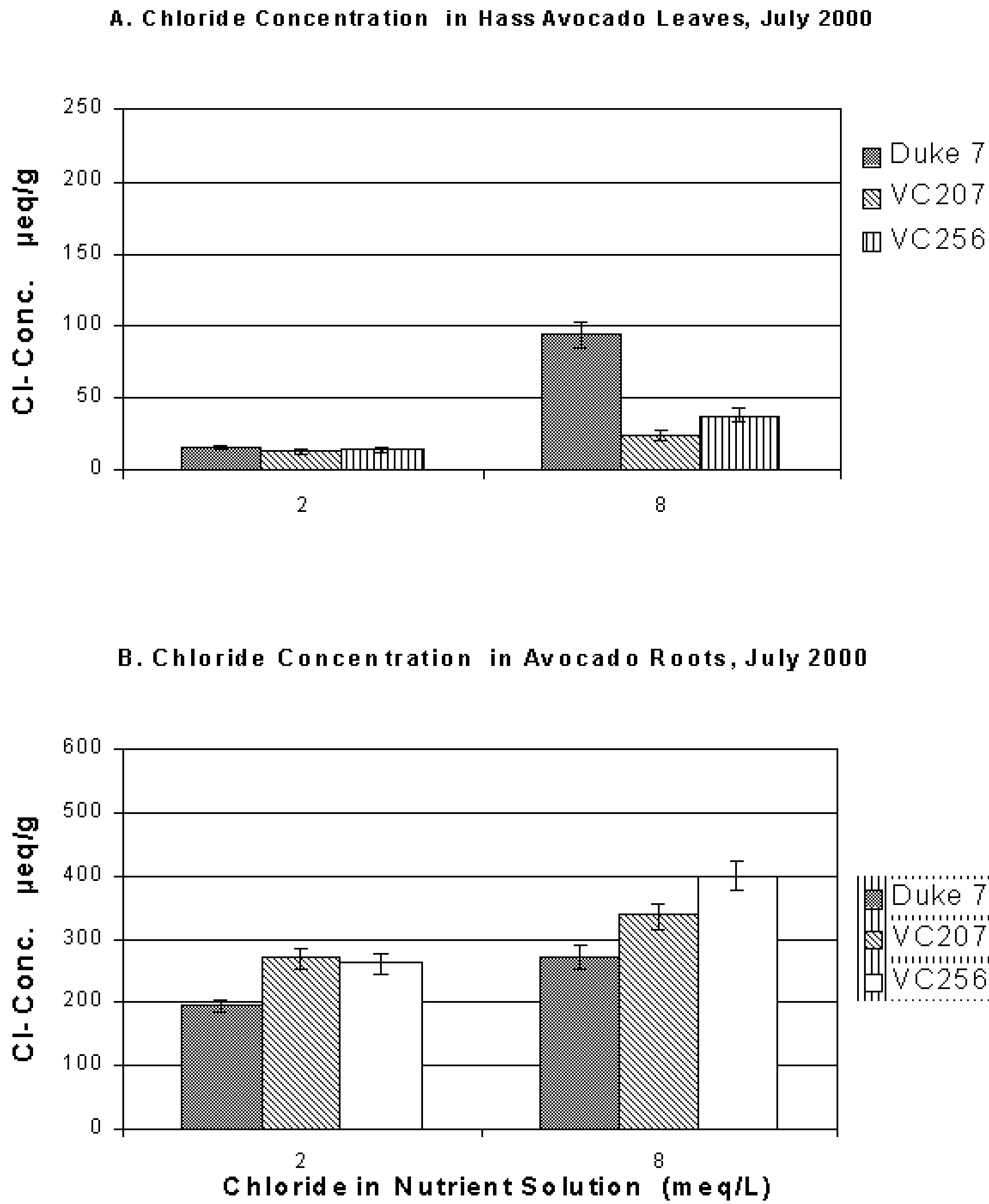

Figure 4. Leaf and root tissue concentrations of chloride for Hass avocado trees grafted on to three different rootstocks grown in hydroponic sand cultures for one year at two different chloride levels. A. Leaf tissue contents. B. Root tissue contents.

Summary

Two West Indian rootstocks VC 207 and VC 256 have been identified which appear to have significantly improved salinity tolerance as compared to Duke 7. The screening program will continue to evaluate several other rootstocks and commercially used materials. A field trial will then be initiated to test these rootstocks under commercial production conditions.

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