Breeding Salinity Tolerant Grape Rootstocks

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Understanding the mechanism of salinity tolerance in any crop plant is a prerequisite to crop development with regards to this trait. However, analogous to agronomic breeding for yield, salt tolerance breeding in grapevines is hampered by the complex nature of the plant response to a soil solution containing a high concentration of salt (reviewed in M. Ashraf and P.J.C. Harris, eds., 2005, Abiotic Stresses, Haworth Press). Salt tolerance is generally regarded as a multigenic trait (T.J. Flowers, 2004, Journal of Experimental Botany 55:307-319) and may be exhibited in at least five distinct control points within a plant (R. Munns et al., 2002, Plant and Soil 247: 93-105). But the importance of understanding and improving salinity tolerance in crop plants overshadows the difficulties involved; in California, an estimated 4.5 million acres of agricultural land contains saline soil, including major grape-growing regions.

Hydroponic culture in a greenhouse is an ideal method for studying salinity stress, permitting precise control of the ionic environment to which the root system is exposed while concurrently minimizing atmospheric variation. Unfortunately, grapevines are ill-suited for most hydroponic systems, often exhibiting symptoms of anoxia within one month. Recently, a continuous-flow recirculating system using lightweight expanded clay aggregate has been tested with grapevines and found to be an effective method of growing grapevines hydroponically (M. Wheatley and G. Cramer, manuscript in progress). In 2007, we constructed an identical system in a greenhouse at UC Davis with the goal of breeding grape rootstocks tolerant to salt stress, and to develop molecular markers for the alleles that confer this tolerance. To date, no such markers have been defined in the scientific literature for grapevines.

Materials and Methods

In 2007 we successfully assembled a continuous-drip hydroponic system in a UC Davis greenhouse currently capable of analyzing 144 grapevines, and expandable to approximately 400 positions. We completed a pilot study designed to optimize salt tolerance screens by using multiple NaCl concentrations, grafted and ungrafted plantlets and a suite of response variables. Our results, while informative, were limited by a high mortality rate, which resulted from the use of newly-rooted dormant cuttings rather than rooted cuttings with a year of root establishment in the field.

Our first of two hydroponics experiments is currently underway and corrections have been instituted to prevent the plant mortality experienced in 2007. This experiment is an improved version of the pilot study, testing the salinity tolerance of Riparia Gloire from two different sources, Ramsey and Thompson Seedless. The results of this study will establish actual root-to-shoot transport rates of NaCl in these selections in three 1-month intervals following establishment, rather than using more common indirect indices of tolerance (e.g., the petiolar Cl^- content of a subjectively selected leaf at a subjectively selected time point). The first of these three harvests is beginning at the time of this writing. This data will provide important insight into the utility, or lack thereof, in developing molecular markers from existing F1 populations of Ramsey x Riparia and Ramsey x Thompson Seedless. Based on data from the pilot experiment, two potentially useful and quickly obtained growth indices will be evaluated against actual transport rates. The commonly used index of petiolar ion content will also be evaluated, as will capacitance at the interface of a petiole-embedded microelectrode, an index of plant water status.

The data obtained from this study should provide a solid foundation for all subsequent grapevine screens.

Hydroponic and soil-based salinity tolerance screening system.

Results and Discussion

Using data derived from the preceding experiments, we will determine optimal conditions by which to assess salinity tolerance in grapevines in this hydroponic system. This information will be immediately applied to a screen of the most commonly-used rootstocks in California: 101-14, 3309C, 1103P, 110R, 420A, SO4, St. George, 5BB, Riparia Gloire, 5C, 140R, 44-53 and 039-16. Additionally, Ramsey and Thompson Seedless will be co-screened as salt-tolerant and salt-sensitive controls, respectively. This data should prove useful to the grape industry in California; additionally, such a data set will be of basic interest because of the known differences amongst these rootstocks with regard to vigor induction or devigoration to the shoot. Separating the effects of vigor from salt tolerance would be useful to grape growers if a salt-tolerant rootstock can be developed that does not excessively induce vigor, or if one already exists but has been inadequately described. Future breeding efforts which seek to independently manipulate these two traits must begin with this preliminary information.

The generation of idealized data from hydroponics in a greenhouse environment permits an evaluation of theoretically less robust data generated from a less expensive study system. We have therefore completed the construction of four 4'x8' trays which are irrigated automatically with a digital controller and three dositrons. We are currently performing a parallel, but expanded, salinity tolerance experiment which uses Riparia Gloire, Ramsey, Thompson Seedless and French Colombard. Each of these genotypes is being tested both on their own roots and with additional plants grafted with a common scion of Pinot Noir.

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