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Genetic variation in *Triticum aestivum* and *T. turgidum* ssp. durum for bicarbonate toxicity associated with high pH soils in South Australia.

by

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Thesis submitted for the degree of Doctor of Philosophy

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September, 2008

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Abstract

In South Australia alkaline soils comprise over 80 percent of the cropping region, with topsoil (0-10cm) varying from acid to alkaline, although the subsoil (>30cm) is almost universally alkaline, typically ranging from pH_w 8.0 to 10.5. In most soil solutions, the pH of alkaline soil is directly related to the concentration of HCO_3^- and CO_3^{2-} and these become toxic at a concentration of approximately 3-5mM HCO_3^- or pH 8.5. Moderate levels of tolerance had been identified in locally adapted bread wheat (*Triticum aestivum*) varieties, with the widely adapted variety Krichauff identified as the most tolerant. Commercial durum wheats (*Triticum turgidum* L. ssp. durum), however, were less tolerant to bicarbonate, which may contribute to their poor adaptation to alkaline soils in comparison to bread wheats.

Bread and durum wheat varieties and populations were grown at several alkaline sites in 2004 and 2005 to determine the influence of high pH on grain yield. At three sites increasing subsoil pH (>8.5) was found to decrease grain yield in the bread wheats, however, at six sites increasing subsoil EC was also found to significantly decrease grain yield in both the durum and bread wheats. At all the field sites, except two, soil EC was measured at toxic levels ($EC_{1:5}$ >400µS/m, Rengasamy 2002, Cooper 2004), but generally soil pH and EC failed to account for a significant percent of the variation in grain yield. In 2004 and 2005, all sites suffered from low soil moisture, particularly in 2004, and multiple abiotic stresses, such as salinity and boron, and biotic stresses, such as crown rot in the durum wheats and stripe rust in the bread wheats. The multiple yield-limiting factors likely inhibited the identification of a single soil constraint at the field sites, particularly a dynamic character such as soil pH.

In many cases the poor performance of durum wheats in comparison to bread wheats on alkaline soils has been associated with poor uptake and nutrient use efficiency by the commercial durum wheats. Durum landrace lines selected for tolerance to bicarbonate solution were generally found to take up less Ca^{2+}, Mg^{2+}, Na^+, and possibly Mn^{2+}, and more Zn^{2+}, K^+, and possibly Fe^{3+} and Cu^{2+} in the field than those lines selected with lower tolerance to bicarbonate solution. Tolerance to bicarbonate, or high pH soils, in durum wheats appears to be strongly related to the ability to extract adequate nutrition from

alkaline soils, as either HCO_3^- toxicity decreases root elongation and reduces the surface area for nutrient absorption, or HCO_3^- prevents the absorption of nutrients and depress their translocation.

A simple screening method was developed to evaluate the tolerance to bicarbonate toxicity in commercial durum and bread wheat varieties, advanced durum breeding lines and durum landraces. A difference of up to 30% in relative root length between bread wheat varieties was identified, yet no varieties were found more tolerant that Krichuaff. In the durum wheat varieties, Kalka was found to be the most tolerant, although had a significantly shorter root length than Krichauff. Several advanced durum lines, however, were found to exceed Krichauff, with parentage that included bread wheat and previously selected bicarbonate tolerant durum landraces. Bicarbonate screening of a further 484 durum landraces from mainly west and south Asia, Europe and north Africa, identified eight percent of landraces as exceeding Kalka for bicarbonate tolerance, offering a potential for improvement in the level of bicarbonate tolerance in commercial durum varieties.

Landrace lines identified as the most tolerant were crossed with Kalka, Tamaroi, or the fixed breeding line Na49/Kalka#4, for the screening of F_2 and F_3 populations. Transgressive segregation was identified in five of the seven populations, indicating that several genes were responsible for the bicarbonate tolerance response in the durum wheats. Further genetic analysis of more closely related bread and durum wheat mapping populations identified a highly significant QTL for root length in bicarbonate solution on chromosome 7A for the RAC875/Cascades and Berkut/Krichauff populations. Other possible loci identified in marker analysis, included regions on chromosome 4A (Cascades), 6D, 3D and 2B (Krichauff) and 7B (Berkut). Quantitative analysis of the Frame/Yarralinka//Pugsley and Wk/TmWLYY9//WLYY9Tm populations, suggested that at least three genes were segregating for root length in bicarbonate solution. Bicarbonate tolerance appears simply inherited, although the response may involve a number of tolerance mechanisms, including tolerance to HCO_3^- toxicity, Zn or Fe efficiency, root vigour or morphology.

Three populations, RAC875/Cascades, Frame/Yarralinka//Pugsley and Wk/TmWLYY9// WLYY9Tm were assessed in the field in 2003-2006 to determine if the difference in root length when exposed to bicarbonate in high pH solution screens corresponded to grain yield. A general positive correlation for root length in the mildly alkaline control and grain yield was found, but unexpectedly, a general negative relationship was identified between the root length in high pH solutions (bicarbonate tolerance) and grain yield. A negative association was also identified between boron tolerance and grain yield in 2003 and 2005 for the Wk/TmWLYY9//WLYY9Tm population. The negative response of grain yield to bicarbonate and boron tolerance is likely associated with the increased absence of available subsoil moisture throughout consecutive growing seasons, from 2003-2006. Bicarbonate tolerant types may have initially provided a higher number of tillers and greater biomass, but with consistently dry finishes to the growing season, may have been prematurely water stressed, reducing the final seed set and grain fill. Further investigation is needed to understand the effect of bicarbonate toxicity and tolerance on the growth of crops throughout the growing season, particularly in relation to the soil water content.

Statement of Originality

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Acknowledgements

I would like to gratefully thank my supervisor, Dr. Anthony Rathjen for his invaluable advice and assistance throughout the project. His guidance and critical analysis of experimental procedures and written work is greatly appreciated. I would also like to thank the Durum Breeding technical staff of Mr. Christopher Stone and Mr. Ranjit Das, and the numerous casual staff, who put in considerable time and effort to assist in field trial preparation, management and harvesting.

Thanks to Dr. Pichu Rengasamy, for invaluable advice on soil chemistry, measurements of soil bicarbonate and carbonate, and the use of laboratory equipment for soil pH and EC measurement. Also to Mr. Colin Rivers for his assistance with use of the soil coring rig and use of equipment for soil testing.

The University of Adelaide for providing funding through an Australian Postgraduate Award, with additional funding through a scholarship established by Dr. A.J. Rathjen from a consultancy fund held by the Durum Breeding group, University of Adelaide.

Dr. Hugh Wallwork, Molecular Plant Breeding CRC, for supplying seed for the double haploid populations RAC875/Cascades and Berkut/Krichuaff, and Kerrie Willsmore for the marker analysis of the populations.

Dr. David Pederson, University of Canberra, for his statistical advice on biometrical genetics.

Finally, I would like to thank by family and friends for their continuing support over the years.