GENETIC STUDIES ON THE TOLERANCE OF WHEAT TO
HIGH CONCENTRATIONS OF BORON

by

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ABSTRACT

This thesis describes studies into the genetic control of tolerance of wheat to high concentrations of boron (B). Initially, experiments were conducted to determine selection criteria for distinguishing between tolerant and sensitive genotypes for both glasshouse and field grown wheat. Responses of plants to high concentrations of B, under glasshouse conditions, included reduced vigour, delayed development, expression of symptoms of toxicity and reduced grain and total dry matter yields. Significant differences between tolerant and sensitive genotypes resulted for all parameters, however the greatest discrimination for tolerance to B, between genotypes, resulted during vegetative growth. Tolerant genotypes accumulated less B than the more sensitive genotypes for both glasshouse and field experiments. The concentration of boron in shoots was a highly heritable character and B concentrations in shoots were significantly correlated between high boron conditions in a glasshouse and the field. The concentration of B in grain was highly correlated with the concentration in shoots for field grown wheat, but this relationship did not occur for wheat grown in pots and the anomalous result was related to the artificial growth conditions. Grain is an appropriate tissue for analysis to determine the B accumulation, and therefore tolerance, for field grown wheat.

The tolerance to B for wheat varieties of historical importance in Australia was investigated. Many of the historically dominant varieties are tolerant to B and all tolerant Australian varieties are interrelated. The initial tolerant varieties were Federation and Currawa and members of the derived family include Ghurka, Quadrat, Insignia, Heron, Olympic, Halberd, Spear and Dagger. The distribution of Insignia, Heron and Halberd followed a similar pattern in South Australia and the regions where these varieties were most widely cultivated corresponds to the regions where the highest concentrations of B have been measured in barley grain samples. Thus, there is correlative evidence that the high concentration of B occurring in the subsoils has been a major selective force in South Australian wheat production.

Tolerance to high concentrations of boron is inherited as an additive character, however expression of tolerance varies from being a dominant to a partially dominant
character depending upon the concentration of applied boron. Major gene control of
tolerance to boron was identified from the segregation patterns of F2 and F3 generations
derived from parents of contrasting tolerance to boron. The parents used represented five
levels of tolerance to boron and the difference between successive levels of tolerance was
under the control of single genes. Three independent single gene differences were
identified. Transgressive segregation resulted between two tolerant lines, Halberd and
G61450, and this suggests they have contrasting genes controlling the uptake of boron. A
genetic model comprising four independent loci, designated Bor1, Bor2, Bor3 and Bor4
was proposed for the five lines. The five lines and their proposed genotypes were:
Kenya Farmer (very sensitive) bor1 bor2 bor3 bor4, (W1*MMC) (sensitive) bor1 bor2
Bor3 bor4, Warigal (moderately sensitive) bor1 Bor2 Bor3 bor4, Halberd (moderately
tolerant) Bor1 Bor2 Bor3 bor4 and G61450 (very tolerant) bor1 Bor2 Bor3 Bor4. As
tolerance to high concentrations of B is under the control of major genes, incorporation of
tolerance into sensitive but otherwise adapted local varieties should be readily achieved
through backcrossing.

The chromosomal location of genes controlling tolerance to B was undertaken by
the use of intervarietal substitution lines, monosomic analysis and interspecific addition
lines. Chromosome 4A of the Chinese Spring - Kenya Farmer substitution lines had a
significant effect upon tolerance to boron and the 4A substitution line was more sensitive
than Chinese Spring. Results for monosomic analysis were inconclusive, however
chromosomes identified as the more probable locations of genes controlling tolerance to
boron included 4A and 7D for analysis of the F3's of (Chinese Spring monosomics *
G61450) and chromosomes 7B, 3A and 2B for reciprocal monosomic analysis between
Chinese Spring and Federation. The Chinese Spring x Ag. elongatum amphiploid was
more tolerant than Chinese Spring and the chromosome 7E addition line was also more
tolerant than Chinese Spring. The results of three separate comparisons therefore
implicate the chromosomes of homoeologous group seven in the control of tolerance to
boron.

Random F4 and F5 lines derived from the tolerant Halberd and sensitive
(W1*MMC) were tested under naturally occurring high B conditions in the field.
Chemical analysis of shoots and grain by inductively coupled plasma spectrometry found uptake of B to be independent of nine other elements. The correlation between tolerance to B, as measured by B uptake, and yield among lines of this population was tested at six sites to identify conditions where tolerance to B resulted in a yield advantage. A significant correlation between tolerance to B and yield resulted only at sites where high boron concentrations of grain resulted. Genetic variation for concentrations of several other elements in shoots and grain also occurred within this population and significant correlations between the efficiency of nutrient uptake and grain yield resulted for Mn at Two Wells and Minnipa while genotypes with low Na accumulation produced significantly higher yields than genotypes with high Na uptake at Rudall. Genetic variation in response to soil elements, other than B, may explain the variable performance of varieties, between environments, and this is an area which warrants further investigation.
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