Chapter 7

General discussion

7.1 Classifying wheat genotypes for boron efficiency

1) In addition to the GSI, the response to low B in wheat cultivars may be distinguished in terms of grains per spike and grains per spikelets. Many authors have reported plant responses to low B expressed as the relative B response, the measurement of plant performance in low B relative to that in sufficient B (e.g. Asad, 2000; Stangoulis, 1998). Thus the relative B response for both the number of grains per spike and grains per spikelet was only about 1% in Kite compared with some 70% in Fang 60, about 50% in 922-211 and 20-30% in the other 3 cultivars.

2) The GSI is a simple and rapid method for assessing B efficiency in wheat. It may be used to screen for adaptation to low B soils of large numbers of genotypes without the B sufficient control (Anantawiroon *et al*, 1997). However, sometimes it may be too insensitive to distinguish between genotypes in similar efficiency classes, e.g. between Kite and SW41 or Schomburgk in this study. In such cases, other measurements of plant performance and a B sufficient control may be necessary. Thus, using a combination of the GSI, flag leaf B at boot stage and relative B response in the number of grains per spike, grains per spikelets, the six wheat cultivars evaluated may be classed into 4 B efficiency groups. Kite is determined to

be very inefficient (VI), followed by 922-211 as inefficient (I), Schomburgk, SW41 and 922-267 as moderately inefficient (MI) and Fang 60 as efficient (E).

3) Previous studies (Rerkasem and Loneragan, 1994; Subedi *et al* 1999) reported that differential response to low B between wheat genotypes could not be indicated by their flag leaf B concentration. However, I have shown conclusively that Kite and Fang 60 in low B were clearly distinguished by their flag leaf B. Furthermore, there is a decreasing trend in flag leaf B concentration at full boot stage from the most B efficient Fang 60 to Kite and the other 4 cultivars in between. The finding that flag leaf B concentration in low B of the other cultivars, including SW41, was not significantly different from either Fang 60 or Kite suggests that low B responses in wheat cannot be generalized.

4) The ranking of Fang 60 and SW 41 in their GSI response to low B was found to relate with their vegetative root dry matter response during early growth. By contrast, in a previous reports vegetative and reproductive responses were not correlated (Rerkasem *et al*, 1993). In the study of Rerkasem *et al.* (1993) the vegetative response to low B was measured by leaf elongation over a 12 days period. The present result also showed no differences between Fang 60 and SW 41 in the shoot response to low B. Root growth appeared to be the more sensitive indicator of vegetative response to low B in wheat.

7.2 The role of B in anther development

1) The B-inefficient SW41 was more sensitive to B deficiency during the critical stage of microsporogenesis than Fang 60.

2.2 Withholding adequate B during the critical stage depressed pollen viability (using FCR test) at anthesis in the B-inefficient wheat cultivar (cv. SW 41) by 40-70 %, produced abnormal pollen wall separation in young microspores, and resulted in the disappearance of mitotic nuclei (using DAPI test). Low B treatment had no effect on any of these pollen characteristics in Fang 60. Unlike previous studies in soil, low B did not impair starch accumulation and the mature pollen contained cytoplasm and organelles. This study has shown that the FCR and DAPI tests are more sensitive than KI/I_2 as indicators of impaired pollen function and viable pollen is not posiyively indicated by the presence of starch.

7.3 Mechanisms of B efficiency

1) The differential response to short-term B deficiency in SW 41 and Fang 60 was associated with significantly lower concentration of B in the ear of SW 41.

2) The B-efficient and inefficient genotypes in this study were distinguishable by the B concentration in their ears. This difference was not detected by others who have reported genotypic variation in responses to low B for male fertility and grain set (Rerkasem and Lordkaew, 1996), including a comparison between SW 41 and Fang 60 (Subedi *et al.*, 1999). In these previous studies, B in the ear was not measured

until booting. By this stage of ontogeny, the B-deficient wheat ear may have continued to accumulate B in the palea, lemma and other nonsexual parts of the ear even though damage to the pollen had already occurred. The present results suggest that it may be feasible to distinguish between the B-efficient and inefficient genotypes by early B analysis of the ear. However, timing of the analysis will be critical. Sampling for the ear has to be done immediately upon the completion of the critical meiotic stage of pollen development.

3) The greater ability of Fang 60 to distribute B into the developing ear may contribute to its tolerance to low external B. The reproductive parts of wheat, the anthers and carpels, were found to require B at greater concentration for their normal development than leaves (Huang *et al.*, 2000; Rerkasem *et al.*, 1997). The greater amount of B distributed into the apical regions of the plant may increase the opportunity for reproductive success.

4) Low B supply changed the pattern of B distribution in the ear between Fang 60 and SW 41, resulting in greater proportion of B partitioning into the ear of Fang 60 than SW 41. This suggests that cultivar difference in sensitivity to B deficiency may be associated with the pattern of B distribution within the plant when B was limited.

5) The present results clearly showed that there was no difference between Fang 60 and SW 41 in B uptake under low B supply, as has also been previously shown (Subedi *et al*, 1999).

6) Boron accumulation in the ear, when external supply was restricted, did not come from the ^{11}B previously taken up by the plant. The greater ^{10}B accumulation in ears of Fang 60 compared to SW 41, with limited external B supply, indicated that B efficiency was associated with xylem transport of B. The greater increase of ^{10}B:^{11}B ratio in the ear of Fang 60 compared to SW 41, over the 5 days of B interruption further indicated that greater B efficiency was associated with a stronger capability for long distance transport of B from the rooting medium into the ear via the xylem rather with than retranslocation of B from vegetative parts.

7.4 Suggestion for future research

This comparative study of Fang 60 and SW 41 has clearly shown that a major mechanism for B efficiency in wheat was associated with the transport of B from roots to the developing ear. More effective transport from the root into the ear under B-limiting conditions contributed to greater B efficiency in Fang 60. However, the relative roles of xylem and phloem loading and unloading in long distance transport of B into the ear remain unclear. In B-sensitive wheat (cv. Wilgoyne), Huang *et al.* (2001) demonstrated that if leaf transpiration is suppressed the amount of B uptake from roots into the non-transpiring ear is depressed. The authors concluded that B transport into the ear was dependent on the long distance transport in xylem driven by leaf transpiration. However, the influence of transpiration affecting translocation rate of mineral elements may depend on the external nutrient concentration (Marschner, 1995). It is possible that under low external B supply, the rate of translocation of B to the ear may be limited by the transpiration activity of the shoot. Further, we suggest that failure in translocation of B from roots into the ear under low B supply may be the result of leaves with high transpiration diverting limited B away from the non-transpiring ear making the ear susceptible to B deficiency. In the study of Huang *et al.* (2001), covering the canopy to decrease transpiration resulted in a relative increase in B uptake into the ear compared to the youngest emerged leaf. This possibility should be examined with a wide range of genotypes from efficient and inefficient classes of B efficiency. Since differential transpiration has been found among wheat genotypes (Richards *et al*, 2001), it would be interesting to examine their response to low B. Alternatively, transpiration in wheat genotypes with known B responses, e.g. Fang 60 and SW 41 should be investigated.