

Effects of Macro- and Micro-Nutrient Supply on Grain Yield and Malting Quality on Responsive Soils

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Introduction

Conditions that favour a crop reaching its full yield potential are moderate temperatures during grain filling, high rainfall, good crop nutrition, disease and weed control, early sowing and an ideal finish to the season. For malting barley, these conditions will also impact on malting quality. Previous work (Long et al., 1997) has highlighted correlations between grain yield and malting quality variables, and environmental and agronomic factors.

A feature of marked significance of many Australian soils is that they have an inherently low fertility status (Williams and Raupach, 1983). Nitrogen (N) and phosphorus (P) management have long been recognised as important to agricultural production, and manganese (Mn) and zinc (Zn) deficiencies are of concern in some areas. Both macro- and micro-nutrients are essential for plant metabolism, growth and development. They are involved in enzyme activation (Mn, Zn), energy transfer reactions (P, N), the electron transport chain (Mn) and they are important constituents of proteins (N). This makes nutrition management an imperative component of malting barley production in terms of yield potential and achieving malting grade.

This paper discusses Mn, P and N experiments conducted between 1996 and 1998 to examine the effects of particular nutrients on grain yield, screenings, grain protein and malting quality.

Methods and Materials

Field Trials

Manganese

Trials were sown at Marion Bay, a Mn deficient site, in 1996 and 1997. The varieties Schooner (moderately efficient), Amagi Nijo (Mn efficient) and Galleon (Mn inefficient) were chosen. Only Schooner was used in both seasons. In 1996, six rates of Mn as Manganese Oxysulphate (28% Mn) was applied and each rate was replicated 4 times. In 1997, the trial was of a split-split-plot design and consisted of 16 treatments that were replicated 4 times. Four rates of Manganese were used with each rate regarded as a main plot. Within each main plot there were four subplots. At stem elongation (10 weeks post sowing) manganese was applied as a foliar spray (Mangasol, 17.3% Mn) at a rate of 6.5 L/ha to two plots and the other two plots received no fertilizer. Mangasol was applied a second time, just prior to anthesis, to two of the plots, while the other two received no application.

Phosphorus

The sites selected were Callington and Geranium (1996) and Sandalwood and Paruna (1997). Both Sandalwood and Paruna were very deficient in P, with soil tests indicating pre-sowing levels of 9 ppm (Colwell available P). Phosphorus (0:17:0:4 NPKS (-Zn)) was applied at 0, 12.5, 25, 50, 75 and 150 kg P/ha. Schooner and Franklin (1996 only) were sown at each site and replicated 4 times to each fertilizer rate.

The 1998 phosphorus trial was sown at Sandalwood only. Phosphorus was applied as double super phosphate (-Zn) at 6 rates; 0, 12.5, 25, 50, 75 and 150 kg P/ha. Each rate was replicated

4 times. The trial design was different to 1997 in that there were paired plots for each replicate of each phosphorus rate. Phosphorus was hand spread over one of the paired plots at a rate of 150 kg P/ha at 12 weeks post sowing only. Uptake by the plant was not expected to be very efficient, but would hopefully boost the level of P in the grain to levels above that achievable with application at sowing only.

Nitrogen

The trial was conducted at Charlick experimental station and consisted of six genotypes and 8 different nitrogen application treatments. The genotypes selected were considered 'inherently' high (WI2875/17 and WI2873), moderate (Schooner and Sloop) or low (WI2808 and Arapiles) in grain protein. The nitrogen fertilizer was applied as urea (46% N) at 0, 25, 50, 75, 100, 120, 50+50 and 60+60 kg N/ha. The 50+50 and 60+60 kg N/ha treatments were split applications at sowing and just prior to anthesis. The trial was designed as a split-plot layout with rate of nitrogen the main plots and genotype the sub-plots. Each rate of nitrogen was replicated 3 times.

Measurements

Grain yield (GY), screenings (SCR) and grain protein (GP) data were collected for each trial. Phosphorus and manganese contents of harvested grain samples were measured by ICP analysis by the Waite Analytical Services Laboratory. Grain nitrogen content was calculated from GP by dividing by the factor 6.25 (Tkachuk, 1969). Grain samples were micromalted and analysed in the Waite Barley Quality Evaluation Laboratory. Malting quality traits determined were malt extract (ME), diastatic power (DP), viscosity (VISC) and malt protein (MP) (1997 Barley Quality Report, SA Barley Improvement Program). All data was statistically analysed by ANOVA (data not shown).

Results and Discussion

Manganese

Grain yield was improved with Mn rate at sowing (Figure 1), and the application of Mn at stem elongation. A reduction in grain protein was associated with the increase in GY. In addition, ME was improved and DP was reduced with both treatments. Application of a second dose of liquid fertilizer, just prior to anthesis, while too late to have a significant influence on GY, SCR and grain weight, did significantly reduce GP and improve ME (Figure 2). An increase in the content of Mn in the grain was also associated with the second dose of liquid fertilizer. The increase in grain Mn content in conjunction with a reduction in GP may indicate that manganese content could alter GP independently of GY.

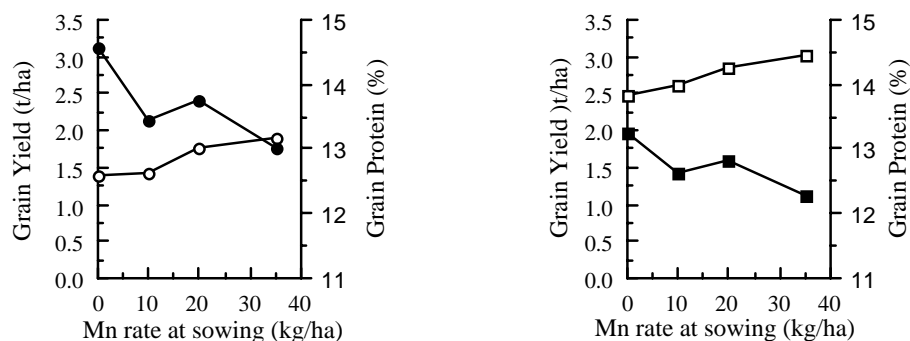


Figure 1: GY and GP response to rate of manganese applied at sowing for the variety Schooner at Marion Bay, SA. ○ GY (1996), ● GP (1996), □ GY (1997), ■ GP (1997).

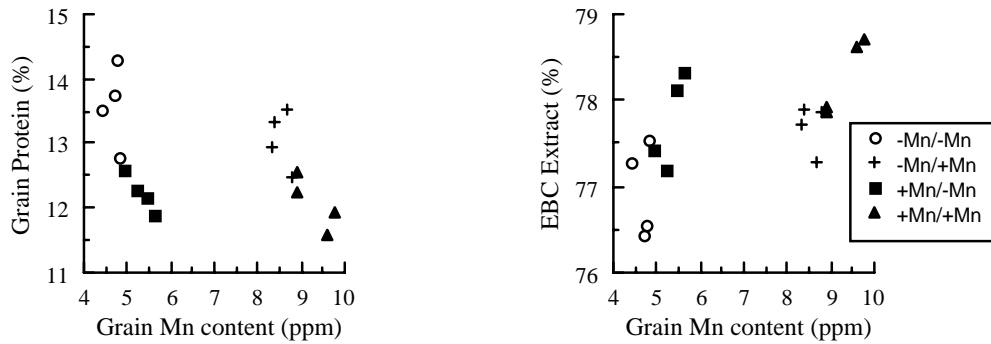


Figure 2: GP and ME response of the variety Schooner to level of Mn in the grain at Marion Bay, SA in 1997.

The alternative to using foliar Mn fertilizers to provide adequate plant Mn nutrition is to sow a variety that grows efficiently on Mn deficient soils. The Japanese variety Amagi Nijo, although poorly adapted, is Mn efficient. The 1996 experiment highlighted that an Amagi Nijo is able to yield almost as well at low and high rates of Mn. The less efficient varieties though were very responsive to Mn application. The fact that they were never better in terms of GY and malting quality than Amagi Nijo, even at the highest rate of Mn, suggests not enough Mn was applied and/or in a form available to the plants.

Phosphorus

The response of GY to rate of P was positive and significant up to 50 to 75 kg P/ha in 1997 and 1998. Any further increase in P application rate had no effect on GY. As expected, GP percentage decreased as GY increased. No significant GY and GP responses were observed in 1996 however (Figure). The effect of P rate on GY and in turn on GP ultimately influenced malting quality. ME improved with P rate, but DP was reduced. At Paruna (1997) and Sandalwood (1998), grain P content improved with P rate, particularly at rates above which there was no GY response. GY (positive-Paruna only), GP (negative), ME (positive) and DP (negative-Sandalwood only) were all correlated to the P content in the grain (Figures 3 & 4). No relationship was observed at Sandalwood 1997, nor Callington or Geranium (1996), between grain P content and MQ characters, since there was no effect of fertilizer rate on grain P content at these sites.

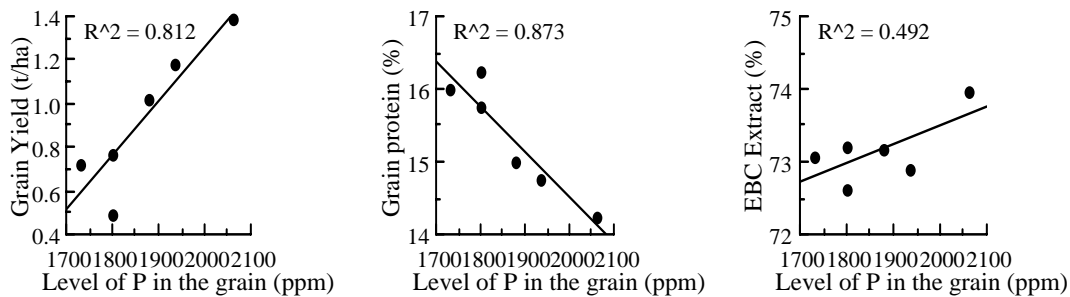


Figure 3: GY, GP and ME response for the variety Schooner to level of P in the grain at Paruna, SA in 1997.

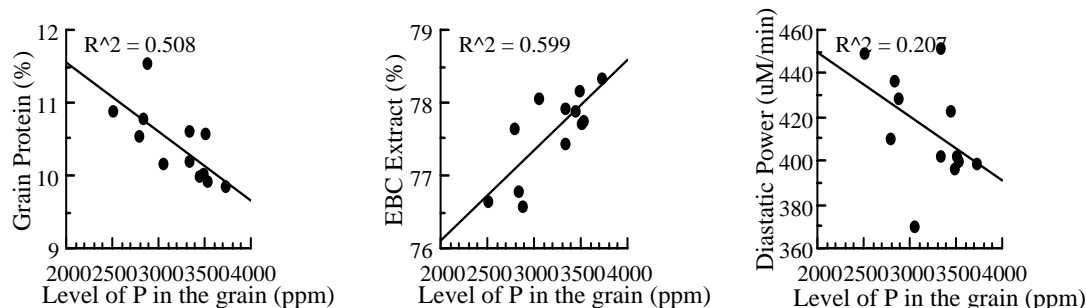


Figure 4: GP, ME and DP response for the variety Schooner to level of P in the grain at Sandalwood, SA in 1998.

Nitrogen

N rate and genotype significantly affected both GY and GP with a significant interaction between N rate and genotype apparent for screenings percentage. The genotypes considered ‘inherently’ low in grain protein (Arapiles and WI2808) were, across all rates of nitrogen, the lowest yielding (Table 1). In particular Arapiles, which is not considered agronomically suited to the drier seasonal conditions in SA, yielded poorly. The lower grain yield of Arapiles may have contributed to higher grain protein, but it was only marginally higher than Sloop, which had a significantly higher GY.

Table 1: Average grain yield, grain protein, and screenings loss, across rates of nitrogen, for 6 genotypes of differing inherent protein at Charlick, SA in 1997.

Cultivar	Inherent Protein	Grain Yield (t/ha)	Screenings (2.2 mm) (%)	Grain Protein (%)
WI2873	HIGH	1.85	33.69	16.09
WI2875/17	HIGH	1.82	39.42	16.62
Schooner	MODERATE	1.85	31.24	16.05
Sloop	MODERATE	1.94	27.39	15.69
Arapiles	LOW	1.48	44.90	15.93
WI2808	LOW	1.58	34.06	14.77
LSD ($P < 0.05$)		0.10	3.59	0.50

Because of the dry seasonal conditions at Charlick in 1997, the high N rates depressed GY and resulted in an increased GP content. As with Fathi et al. (1997), grain protein response was positively and linearly related to nitrogen for all genotypes, with correlation coefficients greater than 0.9. Genetic variation for GP was apparently evident with WI2808 being consistently lower at all levels of N.

While this one site x season experiment showed differences between genotypes in their responsiveness to nitrogen, there was no significant genotype x N rate interaction for either GY or GP. Eagles et al. (1995) found no interaction, Birch and Long (1990) detected an interaction for both GY and GP, whereas Fathi et al. (1997) found an interaction for grain yield only. The responsiveness of barley varieties to nitrogen application has particular importance for malting genotypes. Birch and Long (1990) suggested that it should be possible under N deficient conditions to promote large GY responses at low N rates and maintain a low GP content. Our experiment showed that while GY was highest at the low rates of nitrogen, GP was still too high to meet malting grade specifications. WI2808 was the least responsive in terms of GP, suggesting genetic material is available to potentially produce

varieties that grow in regions where, due to environment, achieving malting grade is difficult because of high protein.

Conclusions

Correlations between plant nutrients and grain yield and malting quality components (Long et al., 1997) do not prove a cause and effect. To elucidate whether there is a direct effect, it was necessary to test these correlations in specific agronomic trials. Increasing the plants access to Mn, P and low rates of N produced an improvement in grain yield. The corresponding reduction in grain protein observed with the Mn and P trials is likely to have resulted from a 'dilution' of nitrogen across more grain. This 'dilution' effect is likely to have impacted on specific malting quality components (ME was improved and DP was reduced), since they are closely correlated to grain protein (Anderson et al., 1941; Rutger et al., 1967; Eagles et al., 1995; Long et al., 1997). Nitrogen management for malting barley however is more critical, for a fine balance exists between improving yield potential while maintaining a low protein content.

This study shows that plant nutrients affect quality variables such as malt extract and diastatic power largely due to an indirect effect on grain protein rather than any direct effect on the malting quality variables themselves.

Acknowledgments

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