Potassium Responses Observed in South Australian Cereals

By Nigel Wilhelm and Jonnie White

Recent field trials in the dryland cropping region of South Australia have demonstrated that unrecognized potassium (K) deficiencies have the potential to severely limit yields.

Potassium deficiency is not currently recognized as a problem in the dryland cropping regions of South Australia. However, the 2001 National Land and Water Resources Audit reported that the region had a highly negative K balance (that is, much more K is exported off-farm in produce than is replaced in fertilizer). Recently it has become apparent that, on some soil types, poor growth of cereal crops may be attributable to K deficiency. In 2002, the South Australian Research and Development Institute (SARDI) established an experimental site in a farmer's field near Laura in the mid North region of South Australia to examine the extent to which cereals may respond to K. The experimental site was on an undulating field with a duplex soil (sandy loam topsoil over a clay loam to clay, calcareous subsoil) and an average annual rainfall of 470 mm. Three field trials were established to test: 1) K rate response, 2) NxPxK interaction, and 3) K application method.

Soil chemical properties from each individual trial area are shown in **Table 1**. Wheat was no-till sown in June and harvested in December 2002. The 2002 season was particularly dry. However, growth of wheat in the trials appeared quite vigorous in the high K treatments. The best treatment at the site yielded 2.78 t/ha, comparable to the region's yield potential based on the amount of rain received.

Rate Response Trial This trial received basal applications of 56 kg nitrogen (N)/ha, 46 kg P_2O_5/ha, 15 kg sulfur (S)/ha, and 1 kg zinc (Zn)/ha. Eleven rates of K (between 0 and 180 kg K_2O/ha) were applied as muriate of potash (MOP) drilled under the seed row at planting.

Table 1. Soil chemical properties measured from trial areas at the Laura site, South Australia.

	Rate response trial		Application trial		NxPxK trial	
Parameter	0-10 cm	10–20 cm	0-10 cm	10–20 cm	A horizon	B horizon
Water pH	7.3	8.1	6.2	6.8	6.6	8.0
Colwell K, mg/kg	45	46	121	53	42	69
Colwell P, mg/kg	27	17	25	16	16	5
Nitrate N, kg/ha	20	11	11	6	4	3
Sulfur, mg/kg	12	11	14	7	6	23
Exchangeable Ca, meq/100 g	5.8	8.5	4.9	5.8	4	11.6
Exchangeable Mg, meq/100 g	0.5	0.5	0.4	0.7	0.4	1.7
Exchangeable Na, meq/100 g	0.10	0.08	0.10	0.06	0.04	0.09
Exchangeable K,meq/100 g	0.13	0.07	0.08	0.14	0.11	0.18
Walkley-Black organic carbon, %	1.4	1.0	1.6	1.0	0.9	0.7

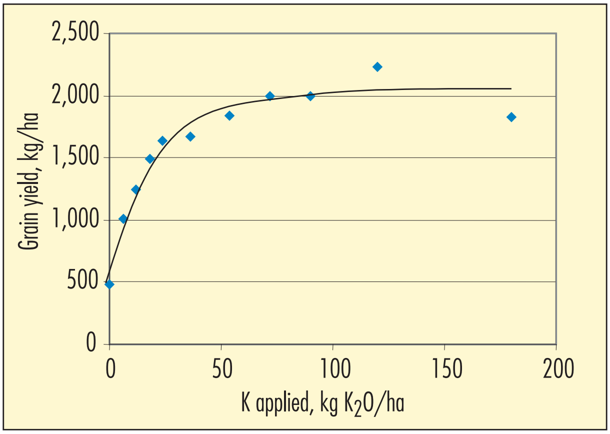
Wheat at tillering, grown with 0 (left) and 120 kg K_2O/ha (right).

Establishment was not affected by the rate of fertilizer K. Early growth was poor on plots without K fertilizer, with plants being paler, weaker, and poorly tillered compared to those grown with a high rate of K (**see photo**). Dry weight of shoots at tillering increased markedly with K. Without K, shoot dry weights were only 190 kg/ha, but increased to more than 700 kg/ha with high rates of K fertilizer. The K concentration of the youngest emerged leaf blades (YEB) at tillering also responded, with maximum dry weight of shoots not obtained until YEB K concentrations were approximately 2%, consistent with published critical values for wheat. The concentration of copper (Cu), Zn, manganese (Mn), and boron (B) in YEB were largely unaffected by rates of K, but the concentration of all other nutrients increased where plants were stunted by K deficiency. This was especially true for calcium (Ca), magnesium (Mg), and sodium (Na), for which concentrations increased by 0.8, 1.7, and 15 times, respectively, from the 180 kg K_2O/ha to nil treatments.

Grain yield was severely affected by K deficiency in this trial. Plots without K yielded less than 500 kg/ha on average, while high rates of K increased yields to more than 2,000 kg/ha (**Figure 1**). While high rates of K were necessary to maximize grain yield, even 6 kg K_2O/ha doubled yield compared to the nil treatment. A Mitscherlich fit of grain yield against rates of applied K estimated that 40 kg K_2O/ha was necessary to achieve 90% of maximum yield. The rate of K had little impact on grain protein. Average protein content for this trial was 9.6%, suggesting that the 56 kg N/ha applied was barely sufficient for normal growth and yield of wheat. The proportion of grain passing through a 2 mm sieve (or screenings percentage) increased at K application rates that resulted in very low yields (less than 24 kg K_2O/ha), suggesting that grain yield is more sensitive to K deficiency than grain size.

Application of K at seeding had no effect on the concentration of K in grain, with an average of 0.45% across the trial. Given on-farm wheat prices in 2002 of A$210/t for APW grade grain, application of K fertilizer at A$450/t would have been highly economical, even at rates above those required for 90% maximum yield. Assuming grain from all treatments had made APW grade, **Table 2** indicates gross income from grain, value of K fertilizer applied, net income after K fertilizer costs, and

Figure 1. Grain yield in response to K application in the rate response trial.



return per K fertilizer dollar invested. In this year, net income per hectare was maximized at 120 kg K_2O/ha.

NxPxK Interaction Trial This split-plot trial comprised one of five N+phosphorus (P) fertilizer combinations (15N + $23P_2O_5$, 15N + 46 P_2O_5, 56N + 23 P_2O_5, 56N + 46 P_2O_5 and 112N + 46 P_2O_5) making up main plots and K applied to sub plots at 0, 60, or 120 kg K_2O/ha as MOP drilled below the seed at planting. This trial also received basal S and Zn applications. Shoot dry weight increased markedly with K fertilizer applied at 60 kg K_2O/ha, but doubling the rate of applied K caused no further increase in shoot weights. A similar response was measured for grain yield (**Figure 2**). Unfortunately, no plant data were available for K_2O applied at 100 kg/ha with the highest rate of N application. Increasing rates of N or P did not improve shoot weights or grain yield unless K had also been applied.

The concentration of K in the YEB at tillering also responded to K application. Without added K, YEB concentrations were very low (1.2% or less). In contrast, all plots receiving K had YEB K concentrations above 2%, except for those with the highest N application (1.9%). This may suggest that 60 kg K_2O/ha was not sufficient where N had been applied at the highest rate. In this trial, grain protein decreased where K was applied, presumably due to a dilution of the available N over a larger grain yield. Increasing the rate of applied N resulted in higher protein content, and P application rate had no effect. The lowest grain protein in the trial (8.9%) occurred with low N, low P, and the highest K rate. The highest grain protein (12.7%) occurred with the highest rates of N and P, and 60 kg K_2O/ha.

Application Method Trial This trial received the same basal nutrient applications as the rate response trial. Potassium was applied as MOP either drilled below the seed at planting (13 kg or 60 kg K_2O/ha), broadcast prior to seeding (60 kg K_2O/ha), broadcast at tillering (60 kg K_2O/ha) or a split application drilled at seeding and broadcast at tillering (30 + 30 kg K_2O/ha)

Establishment was not affected by any of the application techniques used. However, tillering shoot dry weights and K concentration in the YEB were higher where K had previously been applied. Broadcast K at tillering was applied onto dry soil and

Table 2. The economics of K application at the Laura site in 2002, South Australia.

K_2O rate, kg/ha	Gross income, A$/ha	K fertilizer cost, A$/ha	Net income after K fertilizer, A$/ha	Return on K fertilizer, A$ gained/A$ spent
0	96	0	96	-
6	214	5	209	25
12	269	9	260	18
18	314	14	300	15
24	351	18	333	13
36	352	27	325	8
54	396	41	355	6
72	429	54	375	5
90	422	68	354	4
120	468	90	378	3
180	387	135	252	1

little rain fell for the next four weeks. During this time, MOP granules were still evident on the soil surface.

Banding 60 kg K_2O/ha below the seed at planting resulted in the highest grain yield of 2,000 kg/ha. Banding produced 320 and 840 kg/ha more grain than the same rate of K either broadcast before seeding or at tillering, respectively (**Figure 3**). The split application was almost as effective as the same amount of product all banded at seeding. Grain yield was 1,000 kg/ha where no K was applied. This was double the yield of plots without K in the other two trials, presumably due to the inherently higher soil K in this part of the experimental site.

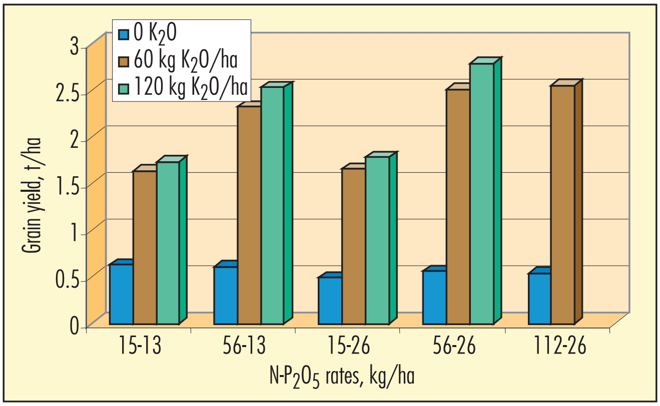


Figure 2. Grain yield in response to the application of K at various N and P rates.

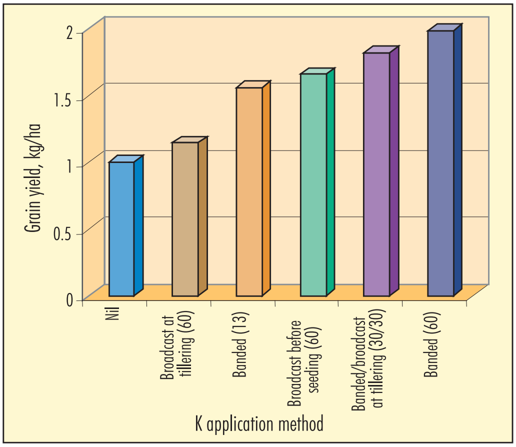
Conclusions

Severe K deficiency was confirmed in these trials, with yield and grain quality markedly improved by K fertilization. Rates of at least 60 kg K_2O/ha were necessary to fully correct K deficiency and produce maximum grain yield of acceptable quality. However, the basal rate of N used (56 kg/ha) was insufficient to avoid N deficiency, as demonstrated by low grain protein, and so a higher rate of K may have been required if adequate N was supplied.

Tools for diagnosing K deficiencies include soil and plant analysis and identification of visible plant deficiency symptoms. In these trials, plants deficient in K were weak, pale, had few tillers and showed signs of chlorosis on the tips and margins of older leaves. **Wheat in soils with levels of up to 120 mg/kg of bicarbonate extractable (Colwell) K responded markedly to K application**, well above the 50 to 60 mg/kg considered adequate for normal wheat production in the sandy soils of Western Australia, suggesting that critical levels for K may need to be revisited. On the other hand, it appeared that published critical values for K concentration in the YEB at tillering were consistent with responses observed in this trial.

Banding K fertilizer below the seed row at planting was the most effective application method. Broadcasting at tillering was ineffective, partly because of dry weather for a long period after application. BC

Figure 3. Grain yield in response to K application technique (amounts shown in brackets, kg K_2O/ha).



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