Potassium Fertiliser Alleviates Drought and Frost Stress in Wheat

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Key messages

- In West Australia, low K soils are common but rates of K fertiliser application are commonly below rates of K removal in grain and hay.
- Based on 21 K experiments since 2011, we conclude that K fertiliser provides added protection for cereal crops against crop stress from drought and frost.
- Adequate K fertiliser addition is important for reducing the effects of crop stress on yield.

Aims

Our aim was to determine whether crop stress (from drought or frost) determined crop response to K fertiliser.

Method

Experimental sites

Since 2011, 21 K experiments with 3-5 K rates from 0 to 120 kg K/ha were conducted in central and southern regions of the grain belt (Table 1, 2). The sites were mostly sandy loams, and soil K test by the sodium bicarbonate extraction (Colwell) ranged from 20 to 140 mg K/kg in the 0-10 cm layer and from 20 to 80 mg K/kg in the 10-30 cm layer.

Experimental treatments

In 2011, four K rates (0, 20, 40, 80 kg/ha broadcast), four application times (0, 5, 10, 15 weeks after sowing) and two K sources (muriate, sulphate) were tested at Dowerin, Bolgart and Borden. In 2012, K rates (0, 40, 120 kg/ha broadcast) by three wheat varieties were examined at a drought prone site in Meckering North, also with K rates (0, 20, 40, 120 kg/ha) by barley on saline soil at Beverley and K rates (0, 40, 120 kg/ha broadcast) by wheat on a frost prone site at Tincurrin. In 2013 and 2014, K rates broadcast (0, 40, 80, 120 kg/ha) with rainout shelter or foliar K and micronutrients were tested at several sites in Wickepin. The K experiments in 2015 (0, 80 kg/ha broadcast plus foliar treatments of two varieties) and in 2016 (0, 20, 40 80 kg/ha drilled below seed plus foliar treatments) were sown four times (every 2 weeks from mid-April) to maximise the likelihood of frost events at critical stages of pollen development in wheat.

Measurements

Weather conditions during the growing season were recorded at the experimental sites or the nearby weather station. Soil moistures in the 10, 40 cm layers were monitored by probes MP406. Canopy temperatures at 60 cm height were measured every 15 min using Tinytags (TGP-4017). Thirty heads per plot were tagged at young microspore stage on the days of frost event, and collected at medium dough stage to assess frost induced sterility (FIS) by dividing total damaged grains by total florets of 30 heads. Top-leaves and heads were sampled at anthesis for measuring K and other nutrients. Quadrat cuts for dry weight were made at anthesis and plant maturity, with machine harvest for grain yield.

Results

Wheat K response under drought

In 2011, regular rainfall occurred in the growing season (May to October) at Bolgart (323 mm) and Borden (247 mm), contrasting with a dry spell at Dowerin with only 28 mm rainfall from mid-August (stem elongation) to mid-October (grain fill) and soil water content (v/v) of 9-10% in the 0-20 cm layer and 12-14% in the 20-40 cm layer. The differences in rainfall and soil moisture between the three low-K sites were related to wheat response to soil K treatments, i.e. K application increased grain yield at Dowerin especially when K treatments were applied at sowing or 5 weeks after sowing, but there was no grain yield response to K at Borden and Bolgart (Table 1, 2). In 2012, the experiment at Meckering North was very dry in July and October and the average of soil water content (v/v) from June to October was 9% in the 0-10 cm layer and 13% in the 30-40 cm layer. As a result, low K-efficient varieties Wyalkatchem and Bonnie Rock had greater K response in yield than K-efficient variety Carnamah. The 2013 and

2014 seasons were mild and the K responses were largely absent, except for the experiments with rainout shelters to keep out the rainfall from early August to early September or from early September to early October. In 2015 and 2016, the rainfalls were low in June (18, 15 mm), September (7, 17 mm) and October (18, 12 mm), and the sowings at or after May normally responded to K application under the dry-finish conditions (Table 1).

Wheat K response under frost

Wheat K response to frost damage was assessed in 2014-2016 according to the methods developed under National Frost Initiative. In 2014 the crop was sown in mid-May. Although severe frost events (-4 °C) occurred in early August, there were only minor frosts from anthesis to grain fill and thus low levels of frost induced sterility (8% at nil K supply). Soil K supply (40, 120 kg/ha) increased leaf K concentration by 0.2-0.5 % but had no significant effect on frost induced sterility (Table 2). In 2015, the plants of the first three sowings (mid-April to mid-May) were damaged by frost events at the young microspore stage, with frost induced sterility of 15-20% at sowing 1, 20-40% at sowing 2 and 15-30% at sowing 3. Potassium supply decreased frost induced sterility by 8% at sowings 2 and 3, but not at sowing 1. The differences in K response could be partly explained by higher leaf K concentration at sowing 1 (2.8% at anthesis in the nil K treatment) than at sowings 2 and 3 (2.4 and 2.0 %, respectively). Yield increases by K supply were 0.1-0.3 t/ha at sowing 2 and 0.2-0.5 t/ha at sowing 3. The results suggest that alleviation of frost damage was the main cause of K fertiliser response in wheat, i.e. additional K fertiliser increased wheat tolerance to frost if the frost event coincided with pollen development unless shoot K was already high (2.8 % or more).

In 2016 at Beverley on a low K duplex soil with 41 mg Colwell K /kg (0-10 cm depth), wheat cv. Mace was sown at four times (13 April, 4 May, 20 May, 10 June) with nil, 20, 40 and 80 kg K/ha together with foliar micronutrients (Mn, Cu and Zn) and K sprays before anthesis. The plants of the first three sowings suffered from frost damage. Frost induced sterility in the nil K treatments was 76% at sowing 1, >95% at sowing 2 and 32% at sowing 3, compared with minor frost damage at sowing 4. When frost damage was extreme (FIS >95%), there was no effect by K on FIS and yield. However, at less severe frosts, K fertiliser at 20-80 kg K/ha decreased the FIS by 10-20%. The decrease in FIS by K supply was accompanied with an increase in yield of 0.18-0.41 t/ha at sowing 3 (Table 1), but contributed little to yield at sowing 1 when the overall yield was less than 1 t/ha (Table 2).

Table 1. **The experiments showed yield response to K supply under dry, saline or frost conditions**

Year	Location	Soil Colwell K (mg/kg) 0-10cm	0-30cm	Leaf K at anthesis of nil K rate	Min K fert. (kg K/ha) for response	Maximum yield (t/ha) with K	Yield increase (t/ha) by K	Crop stress
2012	Beverley (barley)	22	20	0.95 %	20	3.82	0.98	Moderate saline
2011	Dowerin	31	29	0.72 %	20	1.30	0.31	Dry from mid season
2014	Wickepin	36	28	1.29 %	40	3.85	0.42	Rainout shelter
2012	Meckering North	38	35	1.06 %	40	2.11	0.38	Dry in Jul & Oct
2015	Wickepin	42	31	0.98 %	40	2.10	0.54	Dry finish
2016	Beverley (20/5)	42	31	2.17 %	40	3.49	0.41	Frost, dry finish
2016	Beverley (10/6)	42	31	1.21 %	40	2.96	0.47	Dry finish
2015	Aldersyde (29/4)	48	37	2.40 %	80	1.36	0.21	Frost, dry finish
2015	Aldersyde (15/5)	48	37	2.01 %	80	2.94	0.35	Frost, dry finish
2015	Wickepin	55	32	1.10 %	40	2.92	0.59	Dry finish
2012	Tincurrin	140	90	1.71 %	40	2.23	0.33	Frost prone site

Barley K response under salinity

In 2012, barley (*Hordeum vulgare* L.) was grown on a moderately saline (saturation extract electrical conductivity ~4 dS/m) and low K (20 mg K/kg) field at the southwest of Beverley and treated with 0, 20, 40 and 120 kg K/ha. Applying K increased K uptake but decreased sodium (Na) uptake, especially at 120 kg K/ha. Plant growth and grain yield increased with K supply, but the difference between the K rates was relatively small, indicating possible partial K substitution by Na on low-K soils, i.e. Na may reduce plant demand for K. In the cropping area of Western Australia two soil groups, grey deep sandy duplex soil (1.5 Mha) and deep sands (2.4 Mha), have low soil K in coincidence with low-moderate Na amounts, where Na may alleviate the K deficiency. Therefore, the management of K fertilisation on saline soils needs to consider soil K status, crop K requirement, and potentially genotypic variation in the uptake and use of soil Na.

Table 2. **The experiments showed nil response to K supply under mild conditions**

Year	Location	Soil Colwell K (mg/kg)		Leaf K at anthesis of nil K rate	Min K fert (kg K/ha) for response	Max yield (t/ha) with K supply	Yield increase (t/ha) by K	Note
		0-10 cm	0-30 cm					
2011	Borden	33	26	1.30 %	nil	2.51	0.13 n.s.	No dry spell
2013	Wickepin	38	32	1.48 %	nil	4.05	0.01 n.s.	Regular rainfall
2011	Bolgart	40	35	1.62 %	nil	1.77	0.03 n.s.	No dry spell
2013	Wickepin	41	35	1.69 %	nil	4.25	0.22 n.s.	Regular rainfall
2016	Beverley (13/4)	42	31	2.33 %	nil	0.96	0.05 n.s.	Frost dry finish
2016	Beverley (4/5)	42	31	1.74 %	nil	0.45	0.08 n.s.	Frost dry finish
2015	Aldersyde(15/4)	48	37	2.82 %	nil	2.09	0.07 n.s.	Frost dry finish
2015	Aldersyde (2/6)	48	37	1.66 %	nil	2.85	0.13 n.s.	Dry finish
2014	Corrigin	61	48	1.58 %	nil	4.49	0.15 n.s.	Mild weather
2012	Tincurrin	97	76	1.52 %	nil	2.49	0.07 n.s.	Low frost site

n.s., statistically not significant.

Conclusion

In the Western Grains region, low K soils represent up to 50 % of the cropping area. In this environment with a Mediterranean climate, drought and frost are common crop stresses. For the last six years, our experiments showed K fertiliser provides added protection for cereal crops against crop stress from drought and frost. Adequate K fertiliser application is important for reducing the effects of crop stress on grain yield. Grain K concentration is about 0.5%, which means a removal of 10 kg K/ha (or 20 kg muriate of potash/ha) in 2 t/ha of grains and additional loss of K from soil leaching and straw/hay removal. Current rates of K fertiliser on low K soils are generally too low to replace K removal, increase soil K to safe levels, meet demand for high yield crop or achieve ongoing crop protection against stress.

Key words

Wheat, K supply, shoot K concentration, grain yield, frost induced sterility, drought, salinity

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