Frost Increases Internal Potassium Requirements for Alleviation of Sterility and Grain Yield of Wheat (*Triticum aestivum*)

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INTRODUCTION

Low potassium (K) in topsoils and subsoils is common in the grains belt of West Australia (Weaver and Wong 2011). Frost is increasing in frequency and severity during the spring coinciding with the young microspore stage of pollen development, and is manifest as severe grain yield loss from frost-induced sterility. Our aim was to determine whether K increased wheat crop tolerance to frost during early pollen development and whether this was related to internal K concentrations.

METHODS

Two K experiments were conducted in the central region of the grain belt of West Australia (Table 1) on loamy sand profiles, with 48 mg K/kg by the sodium bicarbonate extraction (Colwell) in the 0-10 cm layer in 2015 and 41 mg K/kg in 2016.

The K experiments in 2015 (0, 80 kg/ha broadcast on two varieties) and in 2016 (0, 20, 40 80 kg/ha drilled below seed plus foliar K treatments) were sown four times (every 2-3 weeks from mid-April) to maximise the likelihood of frost events at critical stages of pollen development in wheat cv. Mace.

Weather conditions during the growing season were recorded at the experimental site. Canopy temperatures at 60 cm height were measured every 15 min using Tinytag sensors (TGP-4017). Thirty heads per plot were tagged at young microspore stage of pollen development on the days after frost events, and collected at medium dough stage to assess frost induced sterility (FIS) by dividing total damaged grains by total floret numbers of 30 heads. Top-leaves and heads were sampled at anthesis for measuring K. Quadrat cuts for dry weight were made at anthesis and plant maturity, while machine harvesting was completed at maturity for grain yield.

RESULTS AND DISCUSSION

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. While K fertiliser at sowing increased leaf and head K concentrations at each sowing date, 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). In addition to alleviation of FIS, K supply increased grain yield by 0.1-0.3 t/ha at sowing 2 and 0.2-0.5 t/ha at sowing 3. At sowing date 4, with no FIS, and leaf K concentrations above 1.5 %, the critical concentration (Reuter and Robinson 1997), there was no grain yield response to K fertiliser. 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, 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 it had no effect on yield at sowing 1 when the overall yield was less than 1 t/ha (Table 1). At sowing 4, which experienced negligible frost effects on grain set, leaf K concentrations predicted K deficiency (below 1.5 %), and grain yield did indeed increase with K fertiliser.

Table 1. **The experiments showed yield response to K supply under frost conditions**

Year	Location (sowing date)	Leaf K (%) at anthesis of nil K rate	Maximum yield (t/ha) with K	Decrease in frost induced sterility (%) by K	Yield increase (t/ha) by K	Crop growing conditions
2016	Beverley (10/6)	1.21	2.96	n.s.	0.47	Dry finish
2016	Beverley (20/5)	2.17	3.49	10	0.41	Frost, dry finish
2015	Aldersyde (15/5)	2.01	2.94	9	0.35	Frost, dry finish
2015	Aldersyde (29/4)	2.40	1.36	8	0.21	Frost, dry finish
2016	Beverley (13/4)	2.33	0.96	20	n.s.	Frost dry finish
2016	Beverley (4/5)	1.74	0.45	n.s.	n.s.	Frost dry finish
2015	Aldersyde (15/4)	2.82	2.09	n.s.	n.s.	Frost dry finish
2015	Aldersyde (2/6)	1.66	2.85	n.s.	n.s.	Dry finish

n.s., statistically not significant ($P > 0.05$).

Leaf K concentrations < 1.5 % correctly predicted a grain yield response to K in the absence of frost induced sterility. However, when frost coincided with early pollen development, increasing leaf concentrations in the range 1.5-2.6 % decreased the level of FIS. At leaf K above 2.6 %, there was no additional benefit from increasing leaf K by K fertiliser application. We conclude that increased internal K concentrations were required to alleviate frost-induced sterility and possibly frost induced impairment of other plant functions. At this stage we do not know which plant functions have increased K requirements when exposed to frost, but frost induced a doubling of superoxide dismutase activity in the flag leaf the days following.

In this environment with a Mediterranean climate, frost is a common crop stress but 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.

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