

Crop stress determines response of wheat (*Triticum aestivum*) to potassium fertiliser in a Mediterranean climate



Richard Bell, Qifu Ma



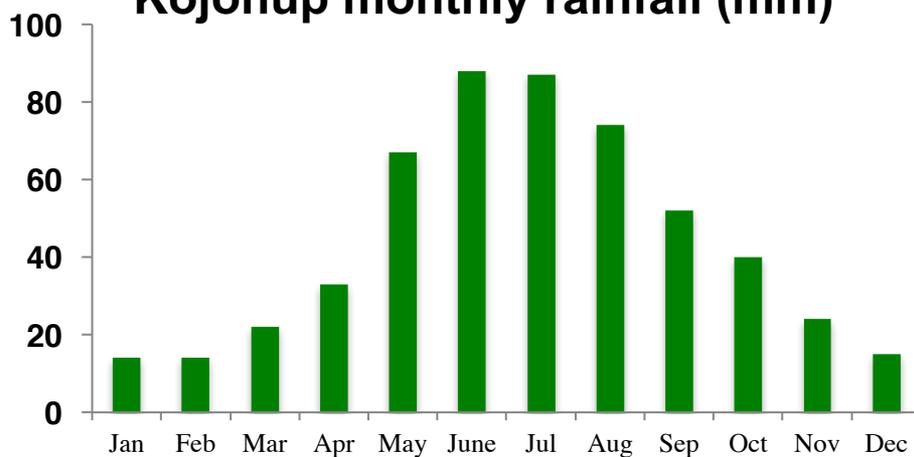
Wheatbelt of West Australia (April- Dec rainfed cropping)



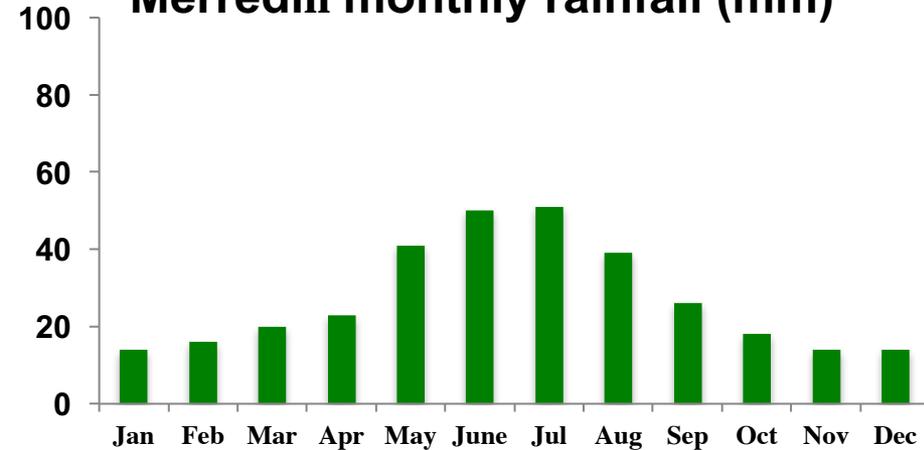
Low rainfall; increasing frost risk

Low but rising yield

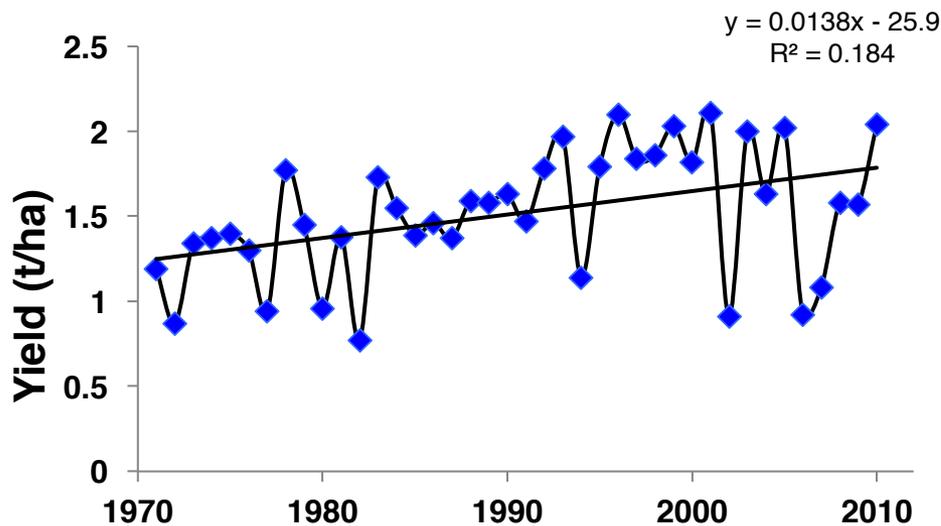
Kojonup monthly rainfall (mm)



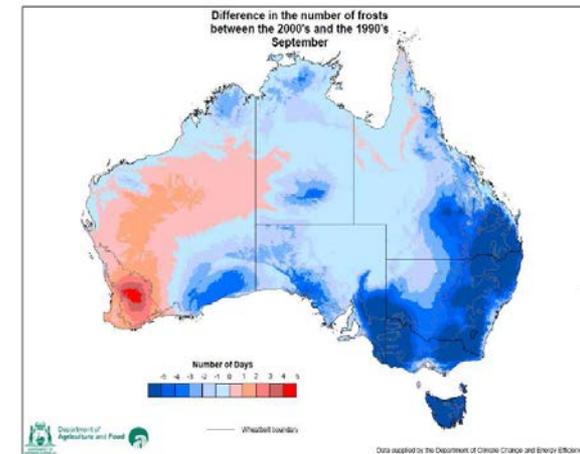
Merredin monthly rainfall (mm)



GRDC Strategic Planning for Investment Based on Agro-ecological Zones – Second Phase



Appendix 9. Difference in the frequency of September frosts in the 2000's compared to the 1990's
(Source: N. Fitzgerald, Department of Climate Change and Energy Efficiency; Data-Fenner School, ANU)



Potential K limitations in agricultural soils of West Australia

(Weaver and Wong 2011- 109,000 soil samples 2008-10)

	Pasture	Wheat
Samples with Colwell K deficiency (%)	49	8
Samples exceeding critical P value and likely to respond to K (%)	29	7



Photo- JW Bowden

Why K?

- Sands are low in K
- K imbalance in cropping/ hay production depleting soil K
- Yield and cropping intensity increasing
- Abiotic and biotic stresses in which K has a role are common:
 - Sodic and saline soils
 - **Frost and drought**
 - Disease

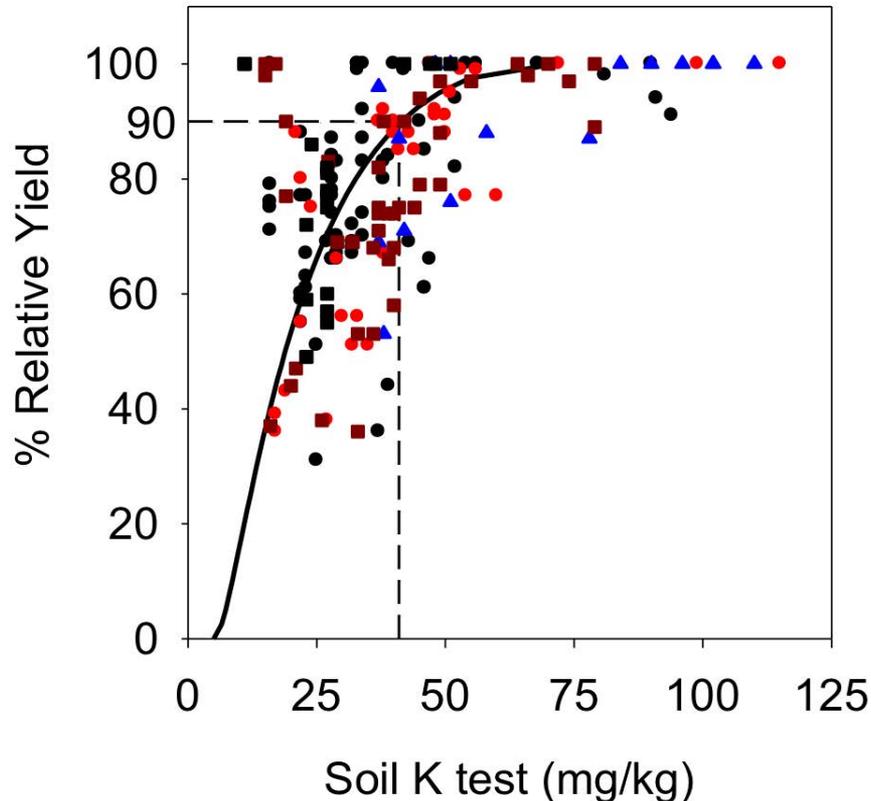


Hypotheses

Stress in crops due to chilling/frost/drought can be alleviated by higher internal nutrient concentrations than required in non-stressed plants

Higher external (soil test) nutrient levels are required to alleviate crop stress due to chilling/frost/ drought

Critical soil K range (0-10 cm, Colwell K): 39 – 45 mg/kg



Critical wheat soil K test for

**All soil types (n=188):
critical range 39 – 45 mg/kg**

**Loams (n=37) :
critical range 45 – 52 mg/kg**

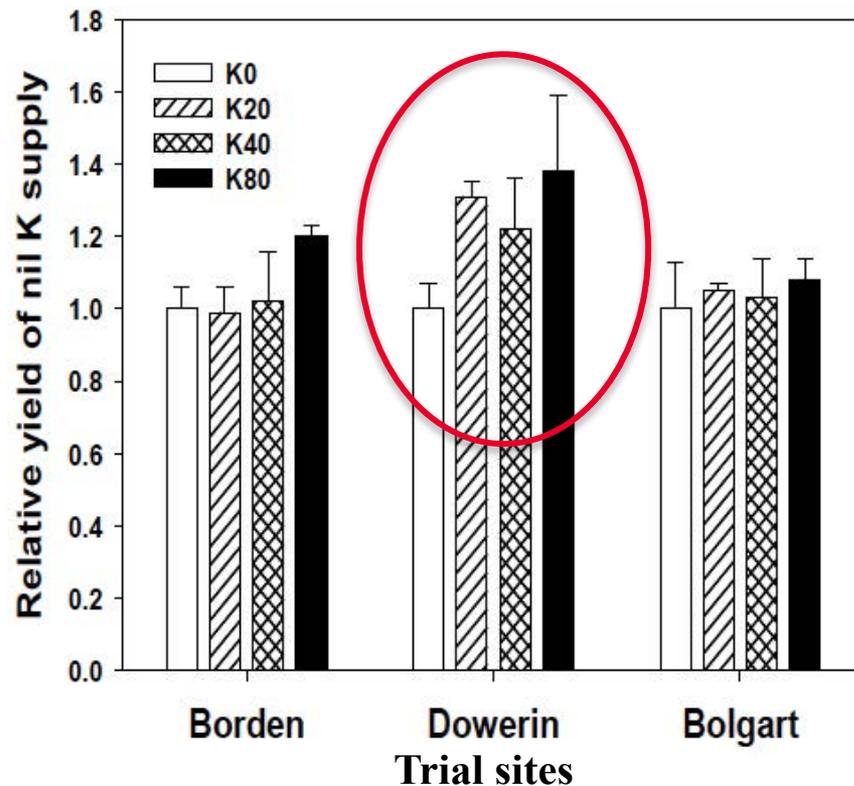
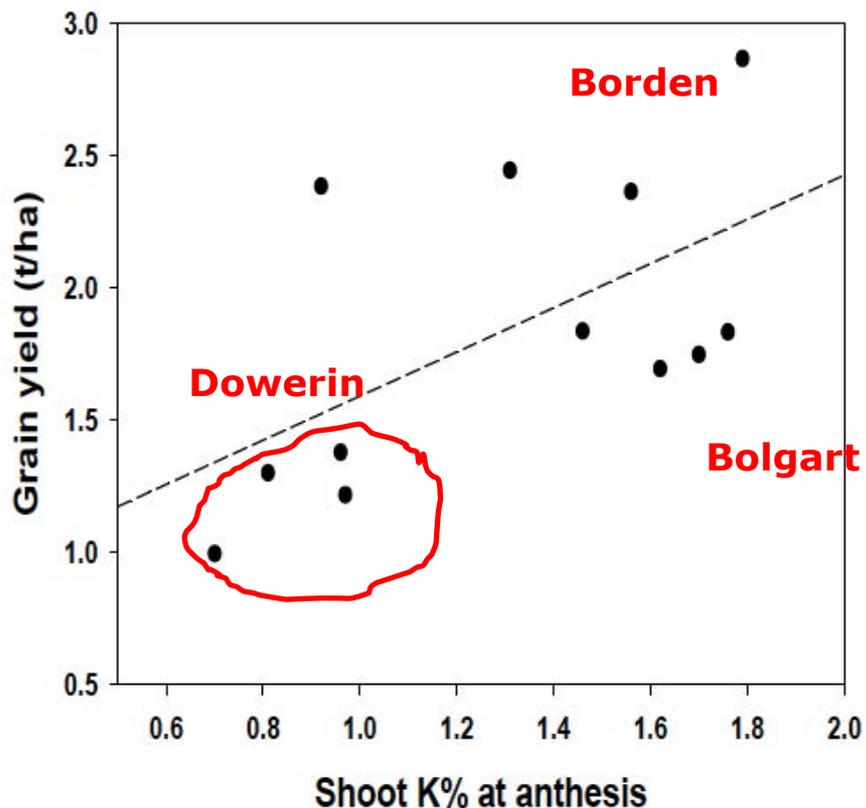
Anderson et al. (2012)

Soil K test (mg/kg) – wheat grain yield response relationship for wheat on Grey sands (■), Yellow sands, (■), gravels (▲), loams (●) and duplexes (●) using soil layer 0-10 cm.

K response of wheat under crop stress



Murdoch



- Soil Colwell K (mg/kg) at 0-30cm: Borden 26, **Dowerin 29**, Bolgart 35

- Rainfall in 2011: regular rainfall at Borden and Bolgart, **but a dry spell from mid-August to mid-October at Dowerin**

K responsive expts

Year	Location	Soil Colwell K (mg/kg)		Maximum yield (t/ha) with K	Yield increase (t/ha) by K
		0-10cm	0-30cm		
2012	Beverley (barley)	22	20	3.82	0.98
2011	Dowerin	31	29	1.30	0.31
2014	Wickepin	36	28	3.85	0.42
2012	Meckering North	38	35	2.11	0.38
2015	Wickepin	42	31	2.10	0.54
2016	Beverley (20/5)	42	31	3.49	0.41
2016	Beverley (10/6)	42	31	2.96	0.47
2015	Aldersyde (29/4)	48	37	1.36	0.21
2015	Aldersyde (15/5)	48	37	2.94	0.35
2015	Wickepin	55	32	2.92	0.59
2012	Tincurrin	140	90	2.23	0.33

K responsive expts

Year	Location	Soil Colwell K (mg/kg)		Leaf K (%) at anthesis of nil K rate
		0-10cm	0-30cm	
2012	Beverley (barley)	22	20	0.95 %
2011	Dowerin	31	29	0.72 %
2014	Wickepin	36	28	1.29 %
2012	Meckering North	38	35	1.06 %
2015	Wickepin	42	31	0.98 %
2016	Beverley (20/5)	42	31	2.17 %
2016	Beverley (10/6)	42	31	1.21 %
2015	Aldersyde (29/4)	48	37	2.40 %
2015	Aldersyde (15/5)	48	37	2.01 %
2015	Wickepin	55	32	1.10 %
2012	Tincurrin	140	90	1.71 %

K responsive expts

Year	Location	Soil Colwell K (mg/kg)		Leaf K (%) at anthesis of nil K rate	Crop stress
		0-10cm	0-30cm		
2012	Beverley (barley)	22	20	0.95 %	Moderate saline
2011	Dowerin	31	29	0.72 %	Dry from mid season
2014	Wickepin	36	28	1.29 %	Rainout shelter
2012	Meckering North	38	35	1.06 %	Dry in Jul & Oct
2015	Wickepin	42	31	0.98 %	Dry finish
2016	Beverley (20/5)	42	31	2.17 %	Frost, dry finish
2016	Beverley (10/6)	42	31	1.21 %	Dry finish
2015	Aldersyde (29/4)	48	37	2.40 %	Frost, dry finish
2015	Aldersyde (15/5)	48	37	2.01 %	Frost, dry finish
2015	Wickepin	55	32	1.10 %	Dry finish
2012	Tincurrin	140	90	1.71 %	Frost prone site

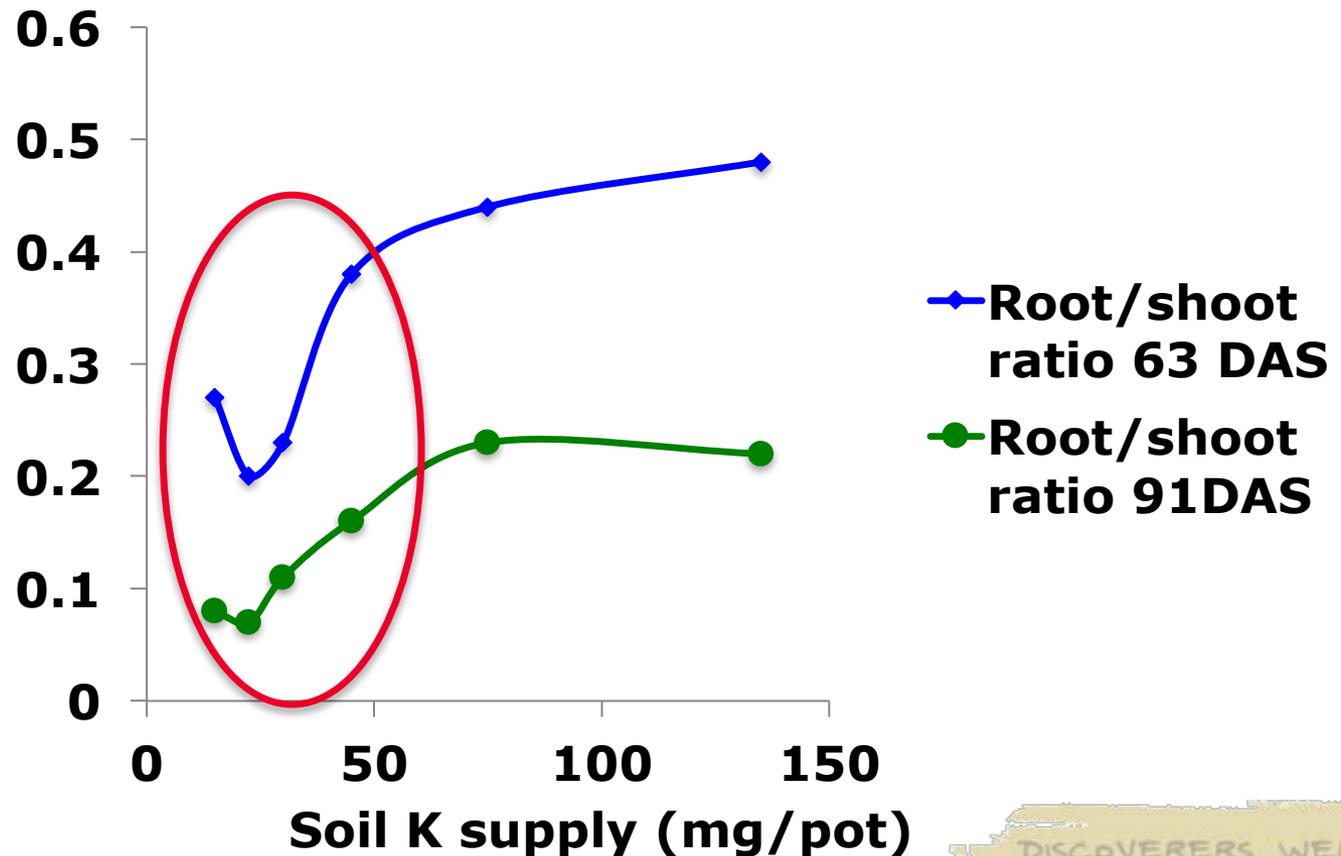


K non-responsive expts

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

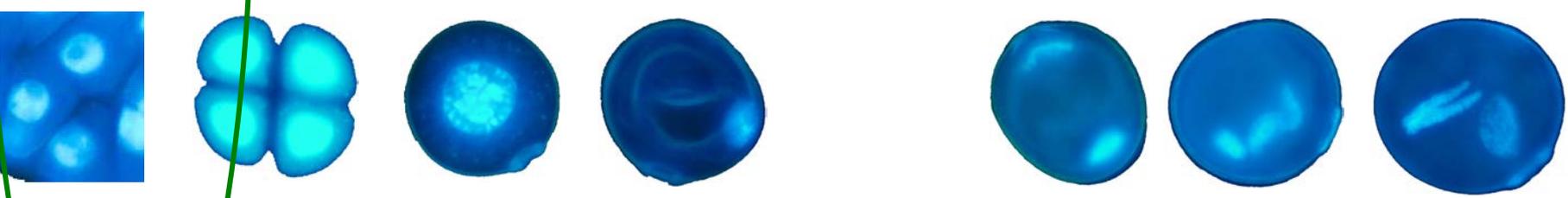
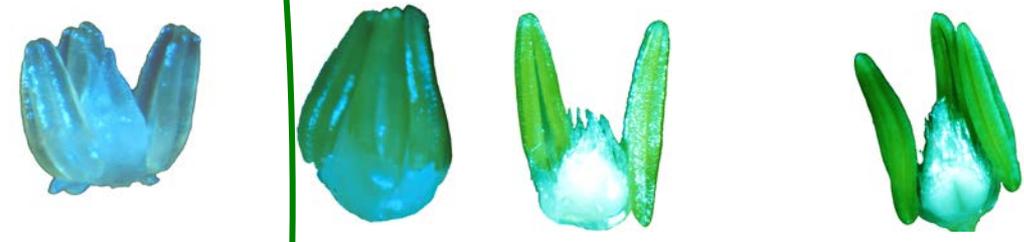
Root: shoot ratio under low K decreased wheat plants

K response of wheat on low K soils
Ma et al. PLSO (2013)





Frost induced sterility – stress prevents pollen development



Sensitive stage of microsporogenesis

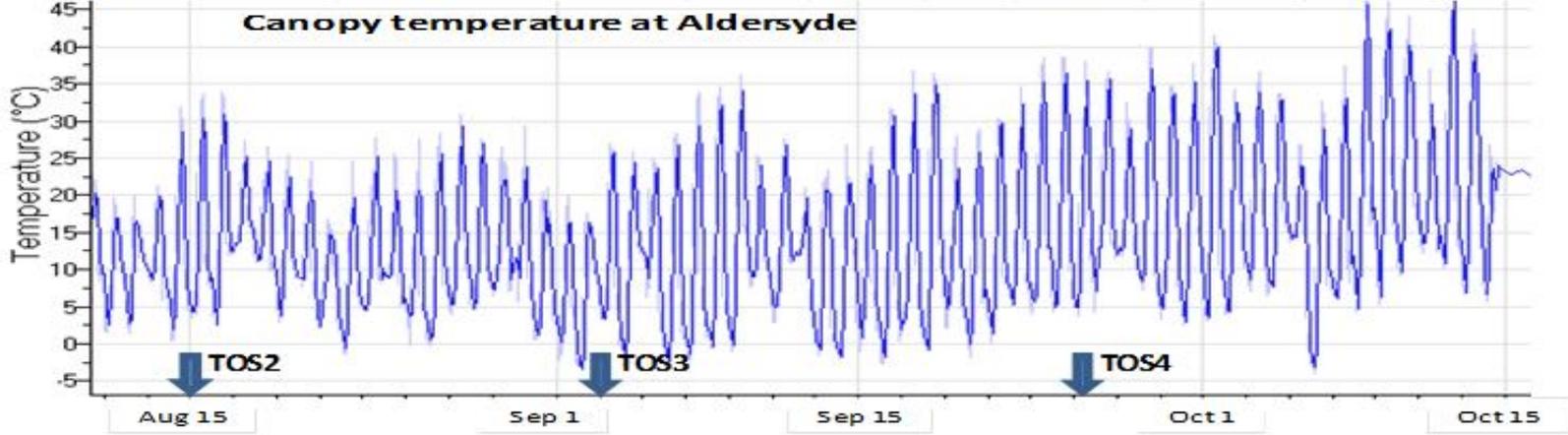
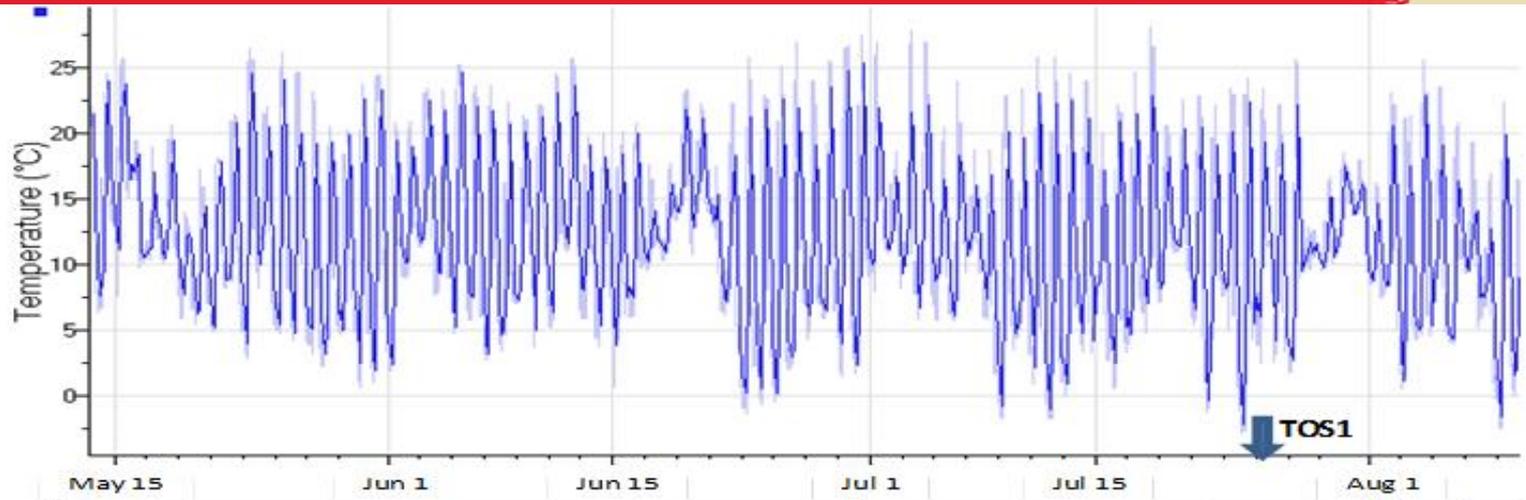
< 2 cm peduncle length)

2015 – Experimental approach

- 2 wheat cultivars (Mace, Wyalkatchem);**
- 4 sowings: 15 April, 29 April, 15 May, 2 June;**
- 3 nutrient treatments (nil, 80 kg K/ha);**
- 4 reps**

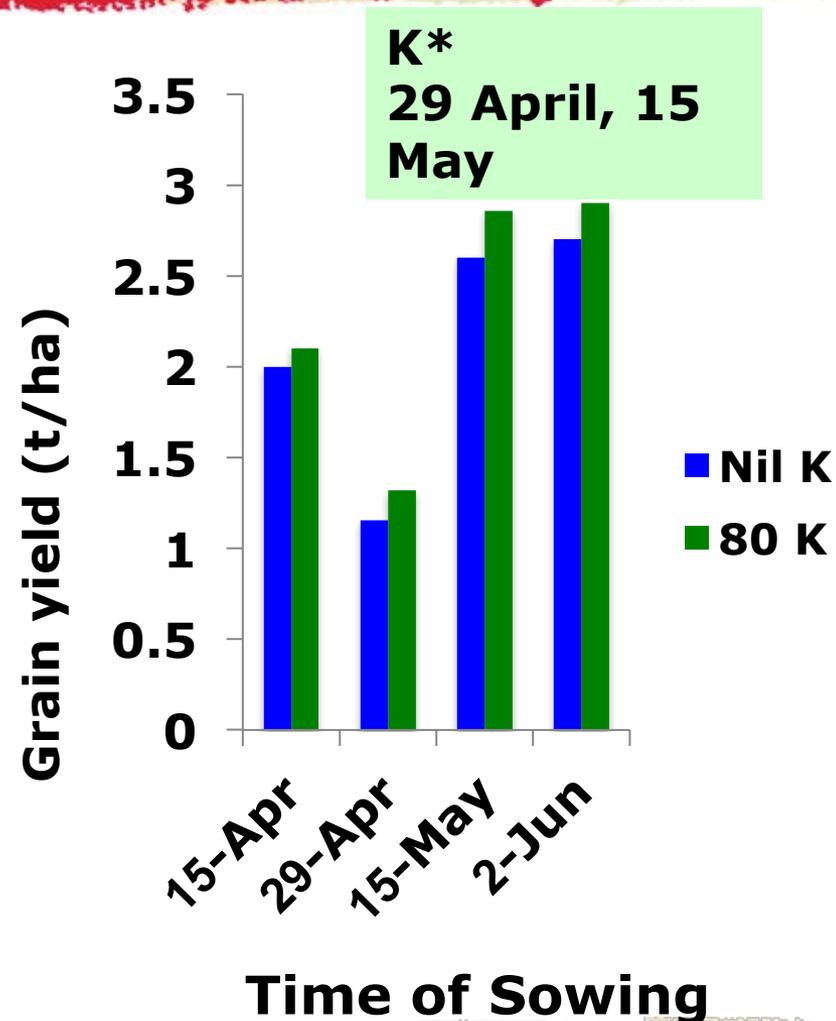
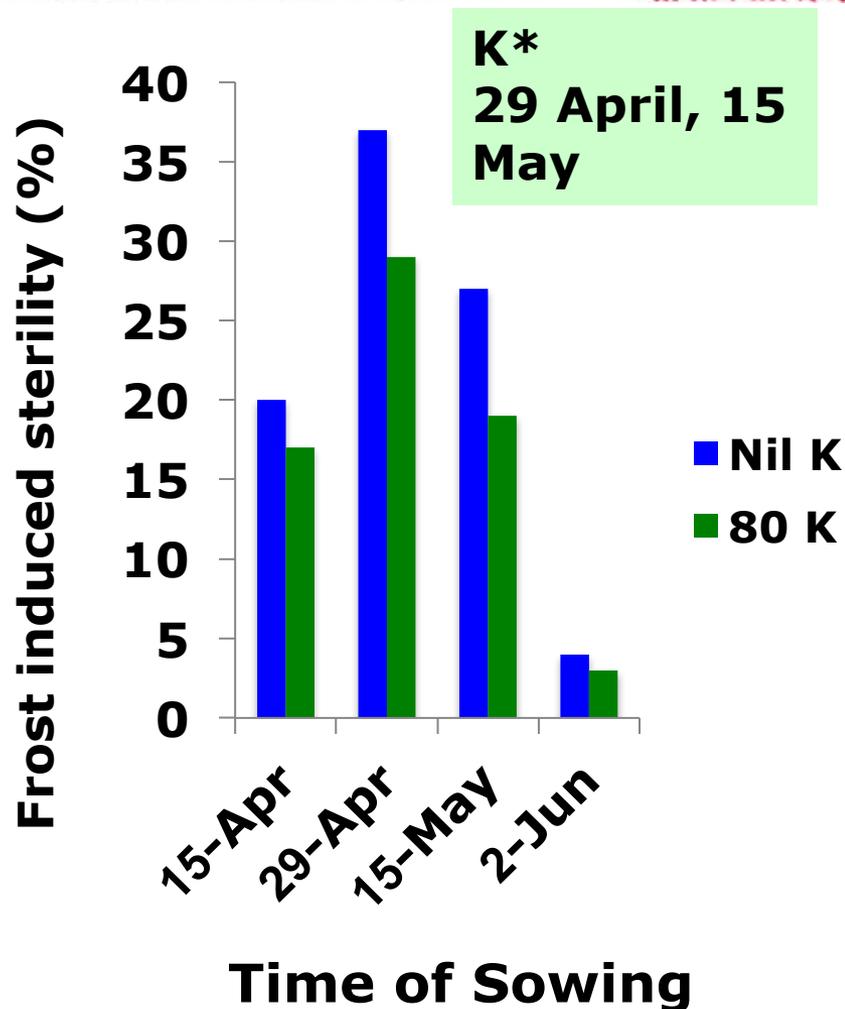
Pre-sowing soil analysis, Brookton

Soil depth, cm	Colwell K, mg/kg
0-10	48
10-20	29
20-30	34



Air temperatures at 60 cm above the ground during wheat growth. The arrows show the flowering time for each of the four sowings.

K reduced frost induced sterility in wheat (Mace and Wyalkatchem) 2015 Brookton



Leaf concentrations of K (%) at anthesis of wheat treated with nil or 80 kg K/ha at booting

	TOS1	TOS2	TOS3	TOS4
Nil	2.8	2.4	2.0	1.7
80 K	3.0	2.6	2.3	1.9
	FIS, no K effect	FIS, K effect	FIS, K effect	No FIS, no K effect

Critical K: 1.5 % K Reuter and Robinson (1997)

Conclusions

- **Low K in soils is common and can be detected by soil testing/ plant testing**
- **Drought stress increases response to K**
- **K increased tolerance to frost induced sterility in wheat (requires higher internal K concentrations)**
- **Mechanisms of increased frost tolerance to K still not defined**
- **Alleviate crop stress with higher K rates than 10-15 kg K/ha to build up soil K levels**

Acknowledgements



**Grains
Research &
Development
Corporation**



Craig Scanlan

Ross Brennan

**Facey Group- Felicity Taylor, Sarah
Hyde, Wade Hinkley**

**Many farmers, especially Gary
Lang, Bill Cleland**

**GRDC –Better Fertiliser Decisions
for Crop; More Profit from Crop
Nutrition 1 and 2; National Frost
Initiative (UMU00030, 00035,
00042, 00045)**

SOPIB- Michel Marchand



Roles ascribed to K in alleviating stress (after Romheld and Kirkby 2010, PLSO)

Increased rate of photosynthesis

Improved translocation of photo-assimilates

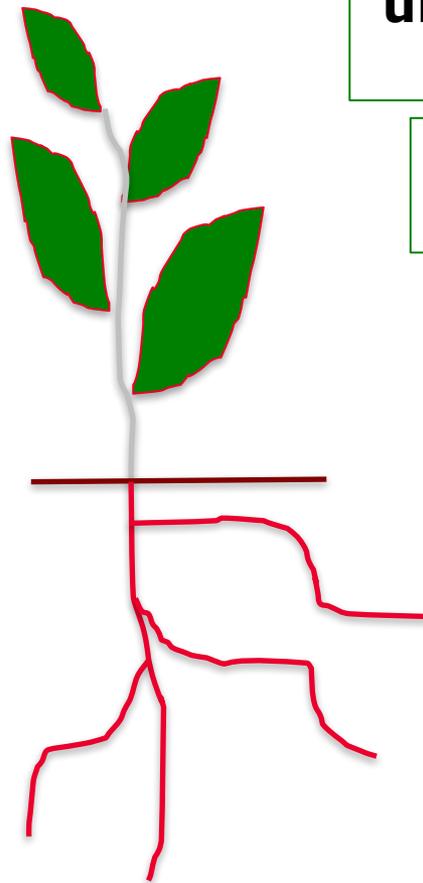
Detoxification of reactive oxygen species

Osmotic adjustment under low soil water supply

Protection of plant tissues against dehydration

Optimised stomatal control for water use efficiency

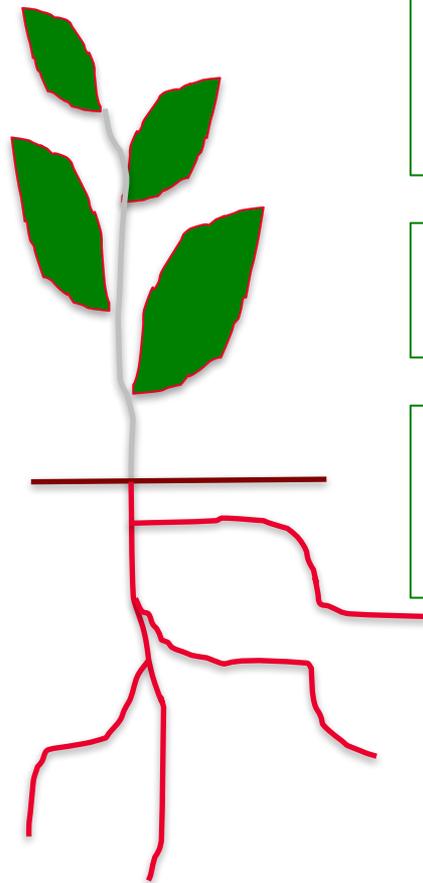
Deeper water acquisition and increased soil water storage



Roles ascribed to K in alleviating frost stress (after Romheld and Kirkby 2010, PLSO)

Lower freezing point of tissue water

Reduced tissue dehydration



Improved translocation of photo-assimilates

Increased photosynthesis

Detoxification of reactive oxygen species

2016 – Experimental approach

1 wheat cultivar (Mace);

4 sowings: 15 April, 29 April, 20 May, 10 June

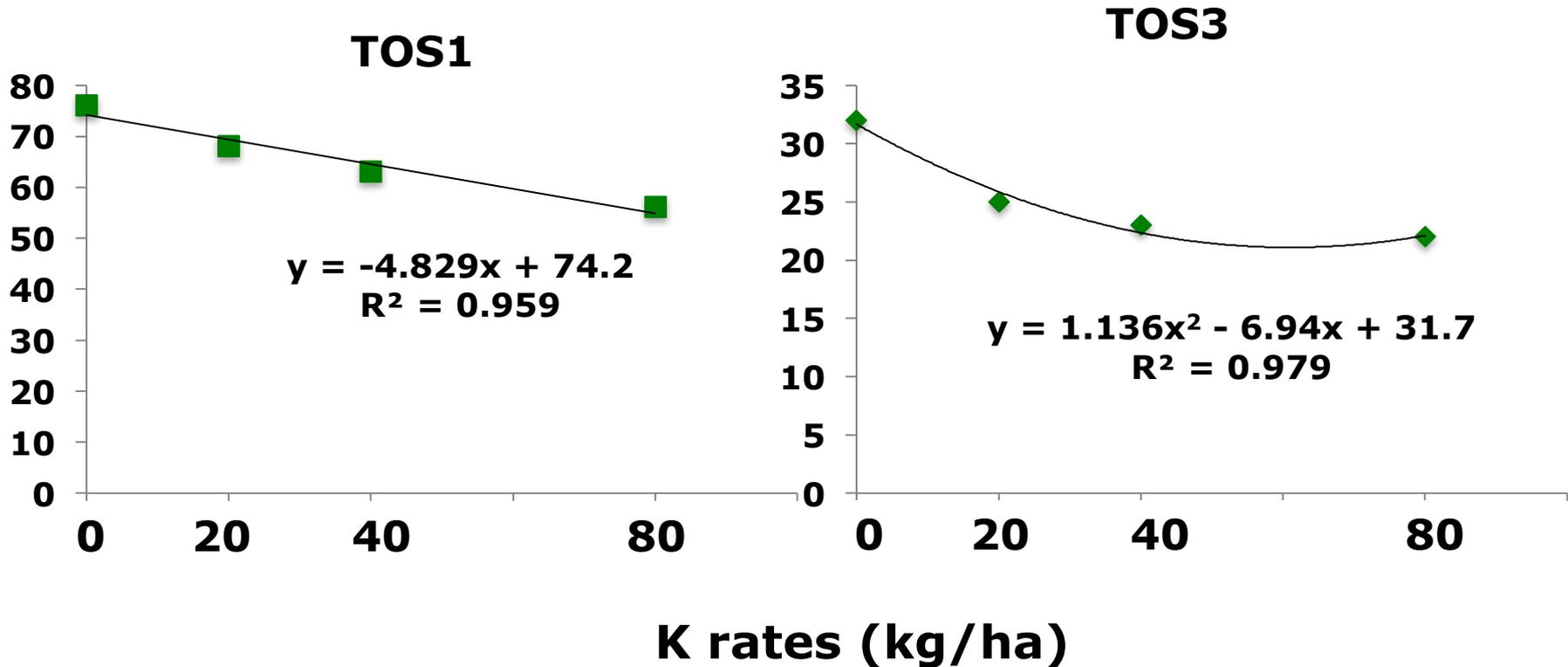
**8 nutrient treatments (nil, 20, 40, 80 kg K/ha,
±foliar TE and K at 0 and 80 K);**

4 reps

Pre-sowing soil analysis, West Dale

Soil depth, cm	Colwell K, mg/kg
0-10	41
10-20	26
20-30	25

Frost induced sterility (%)



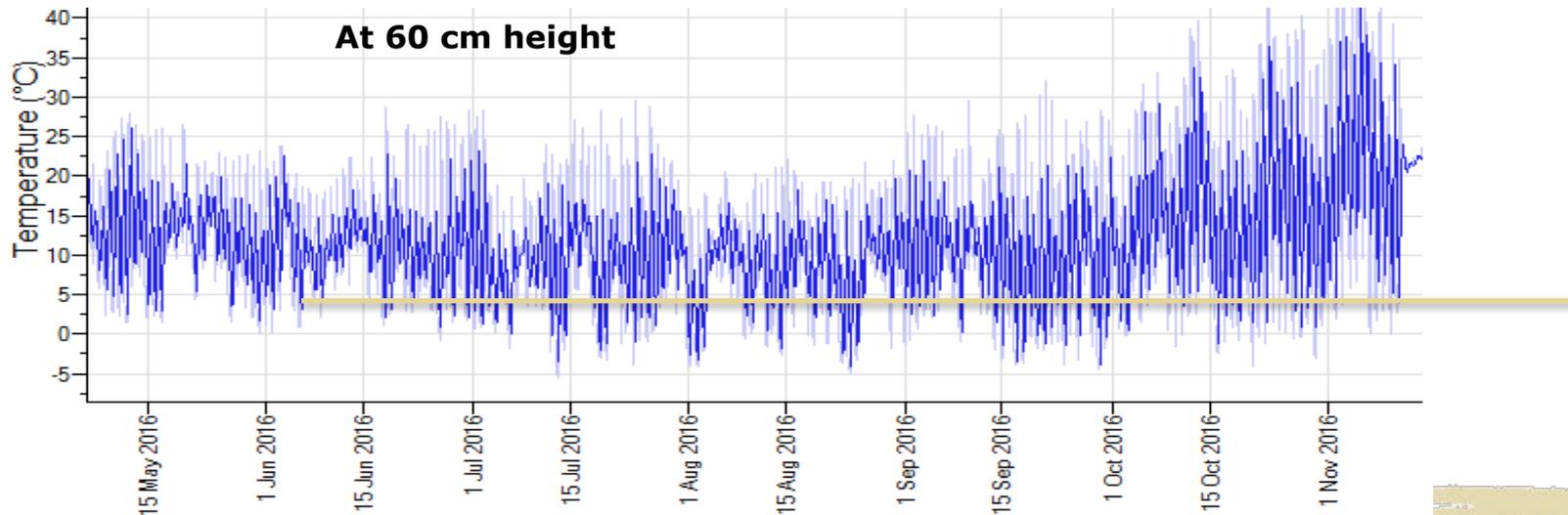
TOS2- >95 % FIS
TOS4- < 6 % FIS

West Dale 2016

**cv Mace;
K banded at sowing**

Heads tagged:

**TOS1, 2 Aug; TOS 2, 26 Aug;
TOS 3, 19 Sep; TOS 4, 3 Oct**



Leaf concentrations of K (%) at anthesis of wheat treated with nil or 80 kg K/ha at booting

	TOS1	TOS2	TOS3	TOS4
Nil	2.3	1.7	2.2	1.2
20 K	2.4	2.1	2.5	1.4
80 K	3.2	2.6	2.5	2.1

Critical K: 1.5 % K Reuter and Robinson (1997)

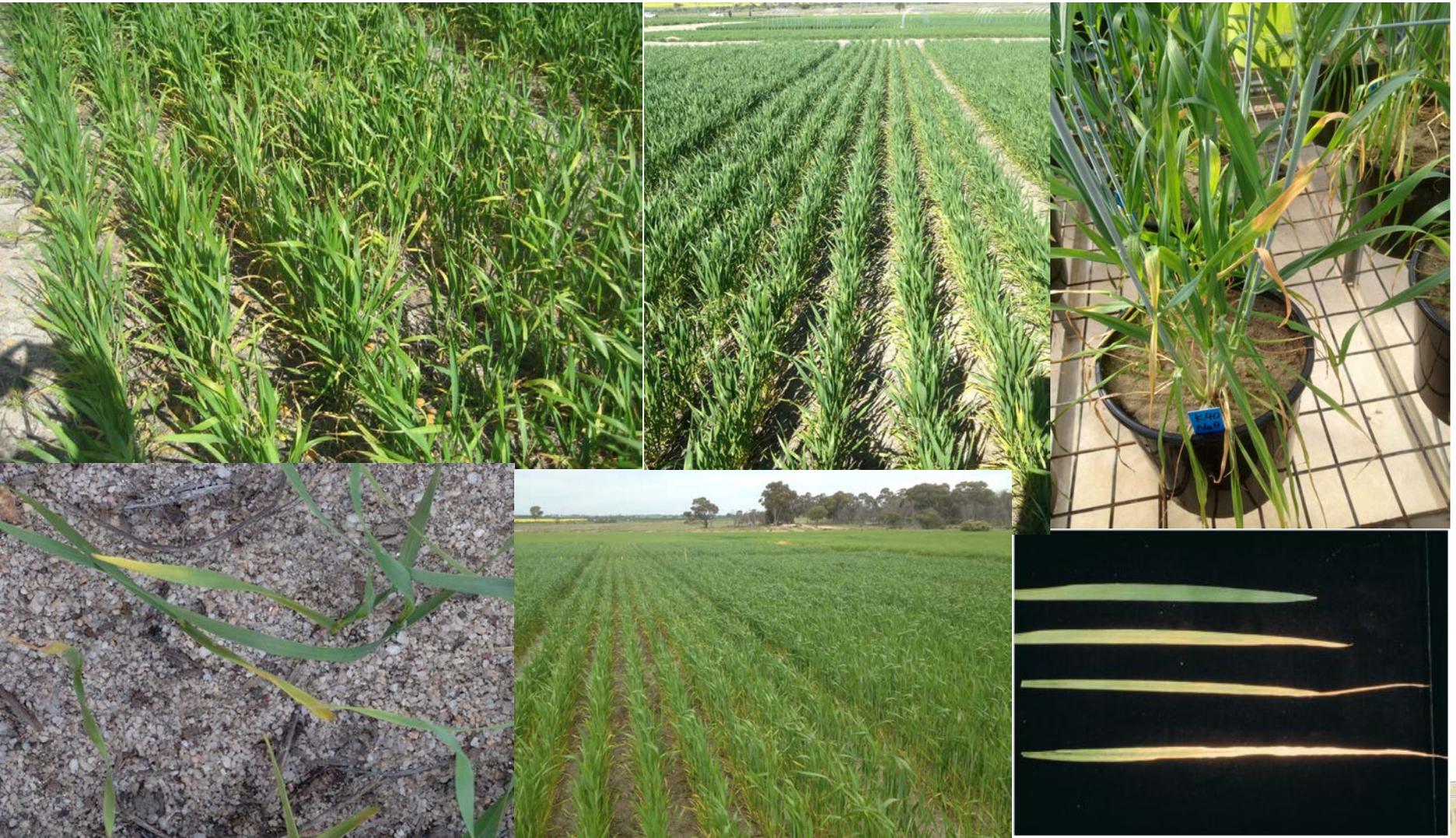
K deficiency symptoms Wheat



Murdoch
UNIVERSITY

<https://www.agric.wa.gov.au/mycrop/diagnosis>

nutrient deficiency in wheat



Mo and cold-responsive genes in winter and spring wheat under cold stress

Sun et al. 2009 *Ann Bot* 104, 345-356

El_Issawi et al. 2013 *Plant Physiol Biochem* 63, 77-81

Gene expression: Mo > aldehyde oxidase > ABA > bZIP-type genes > ABA-dependent and -independent COR genes

Table 1

LT50s for the molybdenum (+Mo) treated and untreated (-Mo) plants in acclimated (CA) and non-acclimated (NA) state.

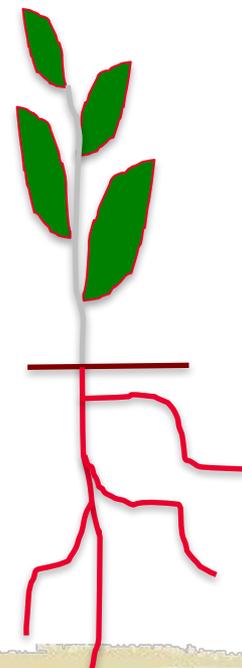
Genotypes	Mo	NA	CA	Δ LT50 due to acclimation	Δ LT50 due to Mo addition	
					NA	CA
Winter	+Mo	-5.43	-8.14	-2.71	-0.27	-1.07
	-Mo	-5.16	-7.07	-1.91		
Spring	+Mo	-5.53	-7.40	-1.87	-0.51	-0.43
	+Mo	-5.02	-6.97	-1.95		

Possible roles of nutrients in chilling and frost resistance

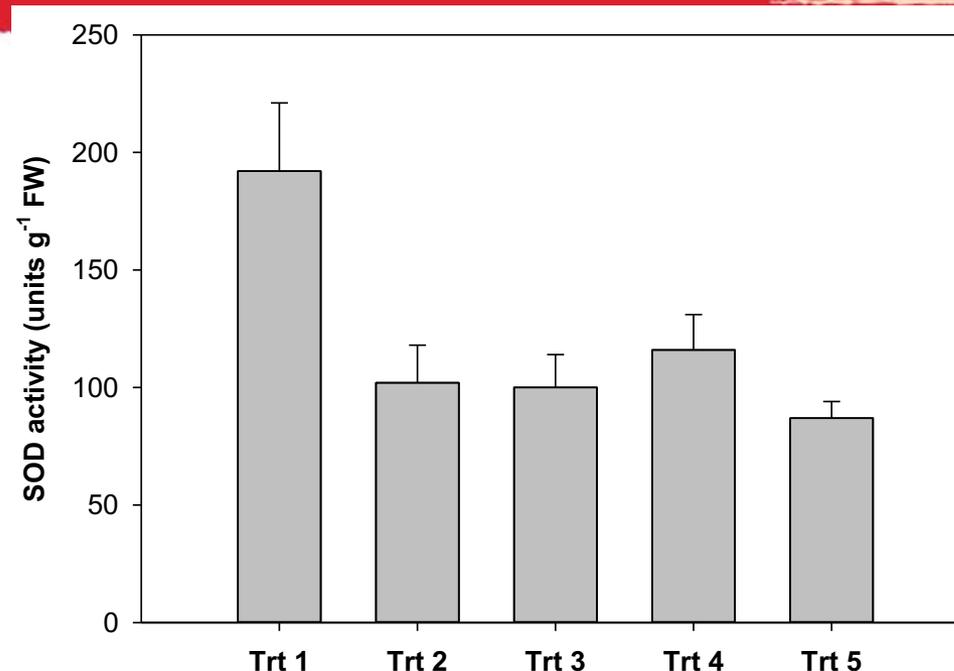
- Lower freezing temperature (K, Mg, Ca)
- Reduced cellular water loss (K, Mg, Ca)
- Increased membrane permeability (B, Ca, Zn)
- Decreased activity of ROS (K, B, Cu, Mn, Mo, Fe, Zn)
- Increased photosynthesis (K, Mg, Mn)
- Increased sugar translocation (K)



PHOTO: SARDI



SOD activity increased nil K following frost



Flag-leaf samples were collected on the following day of a severe frost event (-4 °C). (n=3; capped lines = s.e.)

Trt 1 = nil K supply; Trt 2 = nil K + foliar micronutrients (B, Cu, Zn, Mn, Mo); Trt 3 = 40 kg K/ha; Trt 4 = 80 kg K/ha; Trt 5 = 80 kg K/ha + foliar micronutrients

K responsive expts

Year	Location	Soil Colwell K (mg/kg)		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
		0-10cm	0-30cm					
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