Identifying potassium responsive soils and best practice management where deficiencies occur

Sam Trengove[1], Sarah Noack[1], Nigel Wilhelm[2], Stuart Sherriff[1], Jordan Bruce[1] and Declan Anderson[1]
[1]Trengove Consulting
[2]South Australian Research and Development Institute

Key messages

- Two K response trials (0 and 150 kg K/ha) were established in 2022.
    - At Maitland (Colwell K 98 mg/kg) wheat was responsive to K, increasing in grain yield from 5.4 t/ha to 7.4 t/ha with added K. Residual effects from the K application were also measured the following season in lentil.
    - At Arthurton (Colwell K 200 mg/kg) lentil (2022) and wheat (2023) were not responsive to K fertiliser application.
- Potassium application strategy trials showed wheat grain yields were highest where K (MoP) was banded below the seed at rates of 50 and 75 kg K/ha. These two treatments consistently showed increased biomass, shoot K and K uptake early in the season.
- The response from broadcasting K was variable (no response or moderately responsive) across two seasons.
- Foliar application of K was not an effective application strategy.
- These results suggest the soil test K critical limit for wheat on soils of the Yorke Peninsula is much higher than the 45 mg/kg currently used by the grains industry.

Why do the trial?

Most soils in the Southern region contain sufficient potassium (K) levels for crop production however, deficiencies (suspected or confirmed) are increasingly being reported. Deficiency may first appear as poor crop growth between windrows or header tracks from the previous year.

If a K deficiency is suspected, soil testing is listed as a useful tool to identify the need to apply K to the paddock. However, soils tests on non-sandy soils have not always proven reliable to measure a crop response. This is due to plant available K being present in various pools in the soil and the ability of soil tests (chemical extracts) to accurately measure their availability is not always consistent.

In the southern region predicting crop K response is even less reliable with a soil test as the current critical soil test (Colwell K) values are largely derived from data generated in Western Australia on sandy soils. In the western region K deficiency is more common and the critical value is around 45 mg/kg (41-49 mg/kg) for wheat (Brennan and Bell 2013). There is also limited information on soil test K critical values for crops such as lentils. Another consideration is that some soils on the Yorke Peninsula decline in K with depth, in contrast to other regions where K levels typically increase with depth. down the soil profile.

The project reported here aims to help grain growers diagnose where K deficiency is limiting their productivity and profitability. It also aims to identify the most cost-effective applications of K fertiliser, where they are needed the most, and to avoid wasteful applications where K deficiency is unlikely.

How was it done?

Paddock strip trials

Two K response trials were established at Maitland and Arthurton, SA (Table 1). Both sites were soil cored pre-seeding in 2022. The trials consisted of two K treatments replicated four times; an untreated control and a plus K treatment (150 kg K/ha applied in 2022 only). The fertiliser used was potassium chloride (KCl) also referred to as muriate of potash (MOP) (0:0:50) broadcast onto the soil surface at 75 kg K/ha (150 kg/ha MOP) pre-seeding on 27 April 2022. The remaining 75 kg K/ha (150 kg/ha MOP) was spread 1 week post seeding. Plot size was approximately 5 m x 12 m. In 2023 the strip trials were resown by the farmer and monitored to assess the residual effects of K fertiliser applied in the season prior.

Table 1. Paddock K response trial locations, crop and seeding dates in 2022 and 2023.

Site	Crop and seeding date	
	2022	**2023**
Maitland	Scepter wheat, 17 May	Hurricane Lentil
Arthurton	Highland XT lentil, 17 May	Calibre Wheat, 30 April

Crop assessments across both trial years included an establishment count, a biomass cut and tissue K at GS30 (start of stem elongation) and GS60 (start of flowering). All plots were assessed for grain yield and quality at harvest.

Soil properties

The Maitland site has a loam topsoil transiting to a clay loam at depth (Table 2). The pH was neutral to very slightly alkaline at depth. The site had moderate organic carbon levels (Hughes 2020) and DGT-P was high at 132 ug/L (60 µg/L critical limit for wheat). Colwell K indicates the site had adequate K levels (98 mg/kg) based on Brennan and Bell (2013) 45 mg/kg critical limit. Potassium levels reduced with soil sampling depth. The site had no issues with salinity or sodicity.

The Arthurton site was a clay loam soil with neutral to slightly alkaline pH at depth (Table 3). The soil had moderate organic carbon levels and was deficient in P (<60 µg/L DGT-P). The site had low salinity and sodicity levels to 40 cm below the surface. However, below 40 cm the site was strongly sodic and ECe also increased and may affect sensitive crops. High Colwell K levels (200 mg/kg) were measured in the top 0-10 cm and declined with sampling depth.

Table 2. Soil properties for K response site at Maitland, SA 2022.

Depth	pH $CaCl_2$	Organic Carbon	Soil Texture	Colwell P	PBI	DGT-P	Colwell K	ESP	Salinity EC 1:5	ECe
cm		%		mg/kg		µg/L	mg/kg		dS/m	dS/m
0-10	7.5	1.8	Loam	61	678	132	98	0.8 (Non-sodic)	0.17	1.6
10-30	7.8	0.9	Clay loam	9	203		63	1.5 (Non-sodic)	0.21	1.8
30-60	8.1	0.7	Clay loam	7	212		32	4.5 (Non-sodic)	0.36	3.2

Table 3. Soil properties for K response site at Arthurton, SA 2022.

Depth	pH $CaCl_2$	Organic Carbon	Soil Texture	Colwell P	PBI	DGT-P	Colwell K	ESP	Salinity EC 1:5	ECe
cm		%		mg/kg		µg/L	mg/kg		dS/m	dS/m
0-10	7.6	1.9	Clay loam	46	145	22	200	0.9 (Non-sodic)	0.18	1.5
10-40	8.0	0.8	Clay loam	<5	248		61	4.6 (Non-sodic)	0.31	2.7
40-70	8.3	0.5	Clay loam	5	190		43	15.3 (Strongly sodic)	0.96	8.2

Potassium application strategy trials

Two trials were established to assess a range of K fertiliser application strategies at Maitland; one in 2022 and another in 2023 at a different site. The trials consisted of ten treatments which varied in K fertiliser application timing, rate and placement (Table 4). The trials were sown to Scepter wheat on 24 May 2022 or Vixen wheat on 23 May 2023. Basal fertiliser applied across both sites was 100 kg/ha MAP plus Zn. All K fertiliser was applied as MOP (0:0:50) except the foliar treatment which was liquid Supa K30 (0:0:30). Crop assessments included a biomass cut and tissue K at approximately GS30 and GS60 and grain yield at harvest.

Table 4. Potassium fertiliser treatments for application strategy trials in 2022 and 2023.

Treatment name	Timing	Rate (kg K/ha)
Control		0
Banded below seed	At seeding	12.5
Banded below seed	At seeding	25
Banded below seed	At seeding	50
Banded below seed	At seeding	75
Broadcast	Pre-seeding	75
Broadcast	Pre-seeding	150
Broadcast	PSPE	75
Broadcast	Pre-seeding + PSPE	75+75
Foliar	Stem elongation	1.4 (2022) 1.8 (2023)

**PSPE application dates – 24 May 2022 and 5 June 2023*
Foliar application dates - 9 August 2022 and 10 July 2023.

Soil properties

The Maitland sites in 2022 and 2023 were hosted by the same grower. Both sites had a loam topsoil transiting to a clay loam or sandy loam below 10 cm (Table 5). The pH was neutral to very slightly alkaline at depth. The sites had high organic carbon levels in the top 10 cm (Hughes 2020) and DGT-P was also high at >80 ug/L (60 ug/L critical limit for wheat). Colwell K 0-10 cm indicated the sites had adequate K levels (175 and 138 mg/kg) according to the current industry standard and potassium levels reduced with sampling depth. The trial sites had no issues with salinity or sodicity. In addition to this field observations at the Maitland sites included a high presence of rocks (most likely quartz and lime) at the soil surface. While the top soil was classified as a loam there was a noticeable percentage of coarse sand/fine gravel that could be identified when touched.

Table 5. Soil properties for K application strategy trial at Maitland, SA 2022 and 2023.

Depth	**pH $CaCl_2$**	**Organic Carbon**	**Soil Texture**	**Colwell P**	**DGT-P**	**Colwell K**	**ESP**	**Salinity EC 1:5**	**ECe**
		%		**mg/kg**	**µg/L**	**mg/kg**		**dS/m**	**dS/m**
2022 trial site									
0-10	7.6	2.2	Loam	42	81	175	0.7 (Non-sodic)	0.2	1.6
10-30	7.9	0.9	Clay loam	8		66	1.2 (Non-sodic)	0.2	1.4
30-70	8.1	0.6	Clay loam	6		51	3.7 (Non-sodic)	0.3	2.6
2023 trial site									
0-10	7.2	1.8	Loam	55	104	138	0.9 (Non-sodic)	0.3	2.8
10-30	7.6	1.0	Loam	8		60	1.5 (Non-sodic)	0.2	2.3
30-70	7.7	0.9	Sandy loam	<5		26	2.4 (Non-sodic)	0.3	4.4

Results and discussion

Paddock K response trials – Maitland

At Maitland a response to K application was measured for all crop assessments in year one (Table 6). Early wheat biomass (GS30) was almost double where 150 kg K/ha was applied. Shoot K was also higher at 3.9% compared to 2.4% in the nil. While not well-defined, adequate K levels in whole shoot samples at early growth stages (e.g. tillering up until GS31) are generally around 2 – 2.5% (Brennan 2017; Reuter and Robinson, 2008). Potassium uptake (kg K in shoots/ha), was also almost three times higher where K had been applied compared to 17 kg K/ha in the nil. Similarly, later in the season biomass, shoot K and K uptake were greater in the K fertiliser treatment (Table 6). The addition of K fertiliser increased wheat grain yield by 2.0 t/ha.

In the second season after K fertiliser had been applied, there was still a residual benefit on lentil crop growth, K uptake and grain yield (Table 6). Similar to 2022 there was generally double the biomass growth where K had been applied at both the early and later sampling times. Potassium uptake was higher, resulting in a lentil grain yield of 2.5 t/ha compared to 1.9 t/ha in the nil. These results indicate that the current critical Colwell K value of 45 mg/kg incorrectly predicted a non-response. This site had a Colwell K of 98 mg/kg in 0-10 cm and shows a higher critical value is required for this soil type.

Table 6. Crop biomass, tissue test K, K uptake, and grain yield for Maitland K response paddock trial 2022 and residual effects measured in 2023.

K rate applied in 2022 only kg/ha	Biomass kg/ha	Shoot K %	K Uptake kg/ha	Biomass kg/ha	Shoot K %	K Uptake kg/ha	Grain yield t/ha
Wheat	**9 August 2022**			**10 October 2022**			
0	720 a	2.4 a	17 a	6700 a	0.9 a	58 a	5.4 a
150	1250 b	3.9 b	48 b	9425 b	1.5 b	140 b	7.4 b
Pr(>F)	<0.001	<0.001	<0.001	0.009	0.008	0.006	0.015
LSD (0.05)	105	0.48	7.1	1449	0.306	38	1.26
Lentil	**23 August 2023**			**28 September 2023**			
0	863 b	0.77 b	7 b	2330 b	0.49 b	12 b	1.9 b
150	1495 a	1.47 a	22 a	4670 a	0.86 a	40 a	2.5 a
Pr(>F)	<0.001	0.007	0.001	0.011	0.025	0.001	0.019
LSD (0.05)	212	0.34	2.4	1318	0.282	5.0	0.34

Paddock K strip trials – Arthurton

In contrast the Arthurton site was not responsive to K fertiliser application in either season (Table 7). Lentil crop biomass at both the early and late sampling dates was not improved with K application in 2022. Shoot K results show the concentration in lentil was higher where K was applied. However, when converted to K uptake (kg/ha) there was no difference between the treatments. There was also no grain yield response to K fertiliser application, averaging 4.1 t/ha for both treatments.

In 2023 there was no residual response to K fertiliser in wheat at Arthurton (Table 7). All crop assessments including biomass, shoot K, K uptake and grain yield measured no difference between treated and untreated. This site had a starting soil Colwell K of 200 mg/kg and indicates this level was sufficient for lentil and wheat production on this soil type.

Table 7. Crop biomass, tissue test, uptake, and grain yield for Arthurton K response paddock trial 2022 and 2023.

K rate applied in 2022 only kg/ha	Biomass kg/ha	Shoot K %	K Uptake kg/ha	Biomass kg/ha	Shoot K %	K Uptake kg/ha	Grain yield t/ha
Lentil	**25th August 2022**			**10th October 2022**			
0	930	2.2 b	21	3000	1.9 b	58	3.8
150	875	2.9 a	25	3450	2.5 a	87	4.4
Pr(>F)	0.656	0.008	0.224	0.307	0.027	0.096	0.372
LSD (0.05)	ns	0.33	ns	ns	0.47	ns	ns
Wheat	**10th July 2023**			**12th September 2023**			
0	733	-	-	6433	1.0	63	4.6
150	828	-	-	6735	1.2	83	4.5
Pr(>F)	0.731	-	-	0.481	0.055	0.140	0.942
LSD (0.05)	ns	-	-	ns	ns	ns	ns

Potassium application strategy trial

Early in the season K fertiliser strategy had an impact on all crop assessments at Maitland in 2022 (Table 8). An increase in biomass was measured where K had been banded at seeding for all rates from 12.5 kg K/ha to 75 kg K/ha. Broadcasting K pre-seeding or in combination with PSPE did not improve biomass compared to the control. The only exception was broadcast K at the high rate (150 kg K/ha). Shoot K increased to 4.3% and 5.1%, with rates of 50 kg /ha and 75 kg /ha banded at seeding, respectively. All remaining treatments at GS30 were similar to the control (3.0%).

Later in the season (GS60) no biomass response was measured for the various K strategies (Table 8). Shoot K ranged from 1.6 – 2.0% with minor differences between the treatments. Broadcasting 75 kg K/ha pre-seeding + 75 kg K/ha PSPE resulted in higher shoot K uptake. All other treatments were not higher than the control. In general shoot K at GS60 was not well correlated to grain yield response. Potassium uptake ranged from 107 – 142 kg K/ha with no differences among the K strategies.

Wheat grain yield across the trial averaged 7.22 t/ha. There were only two treatments which improved grain yield compared to the control, the high rates of K (50 and 75 kg K/ha) banded at seeding, with an 8% (0.59 t/ha) increase from 75 kg K/ha. These two treatments also showed increased biomass, shoot K and K uptake early in the season which translated to a grain yield response of approximately 0.5 t/ha. All other K treatments were not different to the control. This indicates broadcasting and foliar application of K were not effective K application strategies. This is consistent with previous field trials which have shown banding K below the seed was more productive than topdressing or pre-spreading (Wilhelm and White 2004).

In 2023 a new trial site was established with the same grower at Maitland to evaluate the same K fertiliser strategies. Similar to the previous season, the 50 and 75 kg K/ha banded at seeding had the greatest effect on biomass, K uptake and grain yield (Table 9), where the best treatment increased yield by 38% (1.37t/ha). However, at this site and season there were also several other K strategies which performed well. Later in the season biomass and grain yield were also high in the 25 kg K/ha banded at seeding and the 150 kg K/ha broadcast split timing (pre-seeding + PSPE). The grain yields from these treatments were closely followed by all remaining K strategies. The only treatment which did not improve grain yield compared to the control was the foliar application.

The greater spread in response among the K strategies in 2023 is likely related to the lower starting soil K (138 mg K/kg) compared to the 2022 trial site (175 mg K/kg). In general, the main findings remain across both seasons. Banding K below the seed was generally more effective than broadcasting, and was responsive to increasing rates. Foliar applied K was not an effective K application strategy in either season.

Conclusions

This series of trials have shown varying responses to K fertiliser application and application method. Four out of six sites/seasons showed significant yield responses to applied K. The initial Colwell K for these responsive sites were well above the current critical soil value of 45 mg K/kg in the top 0-10 cm. This project has shown soil types on the Yorke Peninsula with Colwell K values between 98 – 175 mg K/kg were responsive to K fertiliser applications. Assessment of additional soil types is required to define a more appropriate critical value in our region.

The K strategy trial showed grain yields were highest where K had been banded at seeding at rates of 50 and 75 kg K/ha. These two treatments consistently showed increased biomass, shoot K and K uptake early in the season. The response from broadcasting K was variable (no response or moderately responsive) between the two seasons. Foliar application of K was not an effective application strategy for wheat in these trials.

Table 8. Wheat crop biomass, tissue test, uptake, and grain yield for Maitland K application strategy trial 2022.

Treatment	Timing	Rate kg K/ha	Biomass kg/ha	Shoot K %	K uptake kg/ha	Biomass kg/ha	Shoot K %	K uptake kg/ha	Grain yield t/ha
			9th August (GS30)			10th October (GS60)			
Control		0	514 e	3.0 c	21 c	6691	1.7 bc	107	7.03 cd
Banded below seed	At seeding	12.5	778 bc	2.8 c	22 c	7785	1.7 bc	133	7.32 abc
Banded below seed	At seeding	25	814 ab	3.6 bc	32 bc	7650	1.7 bc	130	7.21 bcd
Banded below seed	At seeding	50	821 ab	5.1 a	47 a	7654	1.8 bc	142	7.42 ab
Banded below seed	At seeding	75	965 a	4.3 ab	42 ab	7975	1.7 bc	136	7.61 a
Broadcast	Pre-seeding	75	616 cde	2.9 c	20 c	7066	1.6 c	123	7.02 d
Broadcast	Pre-seeding	150	725 bcd	3.6 bc	29 bc	7648	1.9 ab	146	7.22 bcd
Broadcast	PSPE	75	520 e	3.2 bc	21 c	6552	1.9 ab	127	7.26 bcd
Broadcast	Pre-seeding + PSPE	75+75	590 de	3.8 bc	26 c	6787	2.0 a	144	7.06 cd
Foliar	GS30*	1.4	704 bcd	2.5 c	20 c	6862	1.6 c	114	7.03 cd
		Pr(>F)	0.002	0.011	<0.001	0.551	0.009	0.558	0.02
		LSD 0.05	180	1.3	14.5	ns	0.240	ns	0.299

**Note foliar application of K was only applied after biomass and shoot K assessment at GS30.*

Table 9. Wheat crop biomass, tissue test, uptake, and grain yield for Maitland K application strategy trial 2023.

Treatment	Timing	Rate kg K/ha	Biomass kg/ha	Shoot K %	K uptake kg/ha	Biomass kg/ha	Shoot K %	K uptake kg/ha	Grain yield t/ha
			27th July (GS31)			29th August (GS61)			
Control		0	334 cd	1.7 cde	6 de	3830 de	1.4 bcd	54 de	3.59 e
Banded below seed	At seeding	12.5	555 a	2.0 bc	11 bc	4450 bcd	1.1 e	48 de	4.24 bcd
Banded below seed	At seeding	25	550 ab	2.3 bc	13 b	5330 ab	1.3 cde	69 bcd	4.58 abc
Banded below seed	At seeding	50	658 a	3.2 a	21 a	6110 a	1.5 abc	93 a	4.63 ab
Banded below seed	At seeding	75	587 a	3.5 a	20 a	5960 a	1.5 bcd	88 ab	4.96 a
Broadcast	Pre-seeding	75	279 d	1.5 de	4 de	4250 cd	1.4 bcd	59 cd	4.31 bcd
Broadcast	Pre-seeding	150	367 cd	1.9 cd	7 cd	4130 cd	1.2 de	50 de	4.17 cd
Broadcast	PSPE	75	415 c	1.9 cd	8 cd	4920 bcd	1.6 ab	78 abc	4.08 d
Broadcast	Pre-seeding + PSPE	75+75	421 bc	2.4 b	10 bc	5220 ab	1.8 a	94 a	4.60 abc
Foliar	GS30	1.4	245 d	1.3 e	3 e	3210 e	1.1 e	34 e	3.30 e
		Pr(>F)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
		LSD 0.05	134	0.4	4	0.92	0.3	21	

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References

Brennan R and Bell M (2013) Soil potassium—crop response calibration relationships and criteria for field crops grown in Australia. Crop and Pasture Science 64 (5) 514-522

Brennan R (2017) Monitoring plant nutrition levels. DPIRD https://www.agric.wa.gov.au/mycrop/monitoring-plant-nutrition-levels

Hughes B (2020) Understanding Your Soils Manual. PIRSA Rural Solutions Coorong LAP Meningie Soil Health Field Day

Reuter D and Robinson J (2008) Plant analysis an interpretation manual. Second edition CSIRO Publishing

Wilhelm N and White J (2004) Potassium Responses Observed in South Australian Cereals. Better Crops Vol. 88 (1)