Horticulture Innovation Australia

Final Report

Improved technique for accurate prediction of soil phosphorus (P) fertiliser requirements in highly alkaline soils.

Dr Robin Harding
South Australian Research and Development Institute (SARDI)

Project Number: PT10005

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Improved technique for accurate prediction of soil phosphorus (P) fertiliser requirements in highly alkaline soils

Barbara Hall et al.

South Australian Research and Development Institute

October 2011

Horticulture Australia

Government of South Australia

SARDI SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Project Title:	Improved technique for accurate prediction of soil phosphorus (P) fertiliser requirements in highly alkaline soils.
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This project reports on methods to improve the existing soil test values in potatoes relative to productivity and the amount of fertilizer to be applied by evaluating the new nutrient soil test technology “Diffusive Gradients in thin Films” (DGT).

This project has been funded by HAL using a voluntary contribution from SA Potato Industry Trust (SAPIT), South East Potato Growers Association (SEPGA) and Yarra Australia Pty Ltd and matched funds from the Federal Government

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1 MEDIA SUMMARY

French fry and fresh potato production are significant horticultural industries in SA. Commercial potato growing requires large amounts of fertiliser so the efficient application and most effective selection of fertiliser combinations are critical decisions for both financial and environmental sustainability of the industry. There has been little information available to help growers determine the optimal phosphorus (P) and potassium (K) fertiliser requirements of potatoes grown for processing in the South-East region of South Australia (SA). It has been suggested that the current P rates may be too high and K rates may be too low.

This project evaluated whether two different technologies developed by University of Adelaide or New Zealand Plant and Food Research could be used assist growers better determine the P and K requirements to maximise yield.

Two replicated field experiments were established on commercial properties in Glenroy in the South East and Parilla in the Murryland districts of South Australia. Soil was collected pre planting for testing, with half sent to Adelaide University and half to a commercial laboratory for the Colwell soil test, used by the industry for many years to determine application rates of fertilisers. Various rates of phosphorous and potassium were applied after planting and yield measured at harvest. However the Parilla site was abandoned prior to harvest due to flooding in December and January that washed out the trial area.

The University of Adelaide used soil collected from the two trial sites to evaluate whether a new "Diffusive Gradients in thin Films" (DGT) soil test could provide more accurate data for growers than the Colwell test. Widely used in the mining industry to extract metals from soil, DGT has been successfully used to measure P in horticultural crops such as tomatoes, and cadmium in potatoes and potato soil.

The pre plant Colwell soil tests results and yields were also provided to New Zealand Plant and Food to compare with the phosphorus and potash best management practice determination using their proven technology "PARJIB" modelling. From results of previous trials in the South East of South Australia, PARJIB predicted clear yield benefits from K fertiliser but no yield response to P fertiliser unless soil P levels were lower than ~10 mg P/kg. A series of recommendations in the form of look-up tables were developed from the model to help growers determine optimal P and K fertiliser application rates that reconcile initial soil nutrient supply and the target yield potential in a given field.

At the South East site, both the Colwell P and DGT soil tests predicted no response from added P, which was confirmed by the yield results. The Colwell K also predicted no response from added K, again confirmed by the yield results. The PARJIB model look up tables also did not recommend any application of phosphorous or potassium.

At the Parilla site, the potassium level was low enough to predict a yield response with added K and the PARJIB model tables recommended application of K. However these predictions were not validated due to the loss of yield data from the flooding.

While the data did not produce conclusive results, it suggested that the DGT test could be an effective alternative to the Colwell method and that evaluation should be continued utilising a greater number of field trials with contrasting soil types. This will better enable the determination of the benefits of DGT technology in the potato industry.

2 TECHNICAL SUMMARY

Two replicated field experiments were established on commercial properties in Glenroy in the South East and Parilla in the Murryland districts of South Australia to evaluate two soil testing methods and their ability to predict P and K needs in potato crops. The Parilla site was abandoned due to flooding in December and January that washed out the trial area.

Soil samples were collected pre planting and used to determine basic indicators (soil pH, Colwell P, Colwell K, exchangeable cations, conductivity) and Diffusive Gradients in thin Films (DGT) testing.

Potato seed cv. 'Russet Burbank' was planted on 20 October 2010. Four rates of P fertiliser (P0, P0.5, P1 and P2) and four rates of K fertiliser (K0, K0.5, K1 and K2) were combined in a factorial design to create a range of soil P and K supply levels. These rates reflected 0, 50, 100 and 200% of the growers' standard P and K practice at the site.

Potato yields were measured in each plot at commercial maturity 161 days after planting (DAP).

DGT soil testing and interpretation was managed by Adelaide University using soil from the two trials managed as part of this project. Colwell soil tests were undertaken by a commercial laboratory in Australia. These results and the yield data from the one completed trial were provided to NZ Plant and Food to incorporate with data from three previous trials to provide recommendations using the PARJIB software.

Outcomes of the project included:

- Establishment of upper limits of DGT P and K critical values for potatoes through non-response.
- Validation of recommendations from look-up tables developed by NZ Plant and Food from the PARJIB model.

Outcomes were presented to growers and industry through mail outs and personal contacts and a grower meeting.

3 TECHNICAL REPORT

3.2 Introduction

Drought and fluctuating global fertilizer prices require growers to make difficult and strategic decisions regarding application of phosphorous (P) and potassium (K) fertilizers. Better decisions will be made if they are based on reliable information including accurate assessment of soil available P and K status. The ideal soil test should measure the form of P and K that is available to the plant from the soil. The soil test should also give reliable information on the available P and K irrespective of soil type. The current extraction methods used such as the Colwell P (Colwell 1963) method can incorrectly calculate these levels as they use a solution containing bicarbonate for extraction. This can also extract relatively stable forms of P (such as calcium phosphates) from the soil that are not plant available. In fact, previous research by Menzies *et al* (2005) and Mason *et al* (2008) showed that Colwell P values tend to be relatively high on calcareous soils despite the fact that crops grown on these soils are renowned for their poor P nutritional status. This is of particular relevance to the South Australian potato industry, where production has expanded into these high pH - highly soluble calcium carbonate soils in the Riverland/Mallee and South East regions.

There has been little information available to help growers determine the optimal phosphorus (P) and potassium (K) fertiliser requirements of potatoes grown for processing in the South-East region. The standard practice in this area has been to apply approximately 75–150 kg P/ha and 200–300 kg K/ha, while an average yielding crop of 50 t/ha removes approximately 25 kg P and 250 kg K/ha in the tubers. The implications are that current P rates may be too high and K rates may be too low.

The technology of Diffusive Gradients in Thin Films (DGT) is used widely in the mining industry to extract metals from soil (Conesa *et al* 2010). Collaborative work between CSIRO and Adelaide University has successfully applied this technology to measure P in horticultural crops such as tomatoes (Menzies et al 2005). While it has been used for cadmium detection in potatoes and potato soil (Perez et al 2009) it has not been validated for use for P detection in potatoes.

PARJIB is a model developed in New Zealand that can analyse and forecast yield responses to nutrients in annual crops, simulating responses to supply of N, P, K and Mg, varying either singly or in combination (Reid *et al* 1999, 2002). By fitting and then applying the PARJIB model for crop responses to nutrient supply, growers could be provided with robust quantitative advice on P and K management practices.

This project evaluated the new soil test technology DGT and compared predictions on response from fertiliser applications to those obtained using the current Colwell methodology. These were compared with recommendations from the New Zealand Plant and Food (http://www.plantandfood.co.nz/) PARJIB Modelling. By providing more accurate soil P and K prediction, growers can better manage fertilizer application rates to potential crop yield on these challenging soil types.

3.3 Methods

Two replicated field experiments were established on commercial properties in Glenroy in the South East and Parilla in the Murryland districts of South Australia. The Parilla site was abandoned due to flooding in December and January that washed out the trial area (Fig 1).

Fig 1. Trial site in early February at Parilla after flooding events

3.3.1 Trial layout.

The 16 treatment combinations were each replicated three times and set up as a randomised complete block. Individual plots were 6 beds wide by 8 m in length, with the two outside beds designated as border rows.

3.3.2 Pre plant soil sampling

Two soil samples were taken from each plot prior to planting. A composite sample of 30 cores at 0- 15cm using 13mm corer was collected from each plot. The sample was mixed and split, with half used to determine basic indicators (soil pH, Colwell P, Colwell K, exchangeable cations, conductivity) and half provided to Adelaide University for the DGT testing. Composite samples of 4 cores using a 25mm corer were collected from 1-25 and 25- 50cm to measure soil mineral N.

3.3.3 Crop details

Potato seed cv. 'Russet Burbank' was planted on 20 October 2010 and irrigated by centre pivot as per normal grower practice. All plots received the same N fertiliser rate (310 kg

N/ha), which was determined using the Potato Calculator™ (www.croplogic.com) and grower experience to ensure N was not limiting. Applications were split-applied as solid urea (100 kg N/ha) at 28 days after planting (DAP) followed by fertigation with liquid N in each irrigation (approximately 6.4 kg N/ha on each occasion). The crop was harvested on 30 March 2011.

3.3.4 Fertiliser treatments

Four rates of P fertiliser (P0, P0.5, P1 and P2) and four rates of K fertiliser (K0, K0.5, K1 and K2) were combined in a factorial design to create a range of soil P and K supply levels (Table 1). These rates reflected 0, 50, 100 and 200% of the growers' standard P and K practice at the site.

All P was applied as single super (8.8%P), while K was applied as sulfate of potash (41% K). Treatments were applied 28 DAP, with the exception of the K2 rate, which was split-applied (50 : 50) at 28 DAP and 59 DAP to avoid any potential toxicity effect on the crop. All applications were surface broadcast.

Table 1. Summary of P and K fertiliser application rates at the Glenroy trial site.

P fertiliser application rate (kg P/ha)				***K fertiliser application rate (kg K/ha)***			
P0	*P0.5*	*P1*[1]	*P2*	*K0*	*K0.5*	*K1*[1]	*K2*
0	50	100	200	0	150	300	600

[1]P1 (100kg P/ha) and K1 (300 kg K/ha) reflected the standard grower practice at the trial site. All plots received 310 kg N/ha.

3.3.5 Crop measurements

Potato yields were measured in each individual plot at commercial maturity (161 DAP). Tubers were dug from the middle 2m of each row from the centre three beds. Tubers were graded into five size categories (0–75 g, 75–100 g, 100–170 g, 170–340 g, >340 g), counted and weighed fresh. A 3.5 kg composite sample (tubers above 75 g) from each treatment was oven-drying at 75ºC for 7 days to estimate percent dry matter (DM).

3.3.6 Analysis

The DGT soil testing and interpretation was managed by Adelaide University for both trial sites.

Soil basic indicator tests were performed by the commercial laboratory CSBP Ltd in Western Australia. Soil tests from the flooded Parilla site were not completed.

Data were provided to NZ Plant and Food to provide recommendations using the PARJIB software.

3.3.7 Critical value determination – phosphorous (P)

The Critical Colwell P, the level above which no response to additional P is predicted, was calculated using the buffering index (PBI) interpretation of Moody (2007) (Fig. 2).

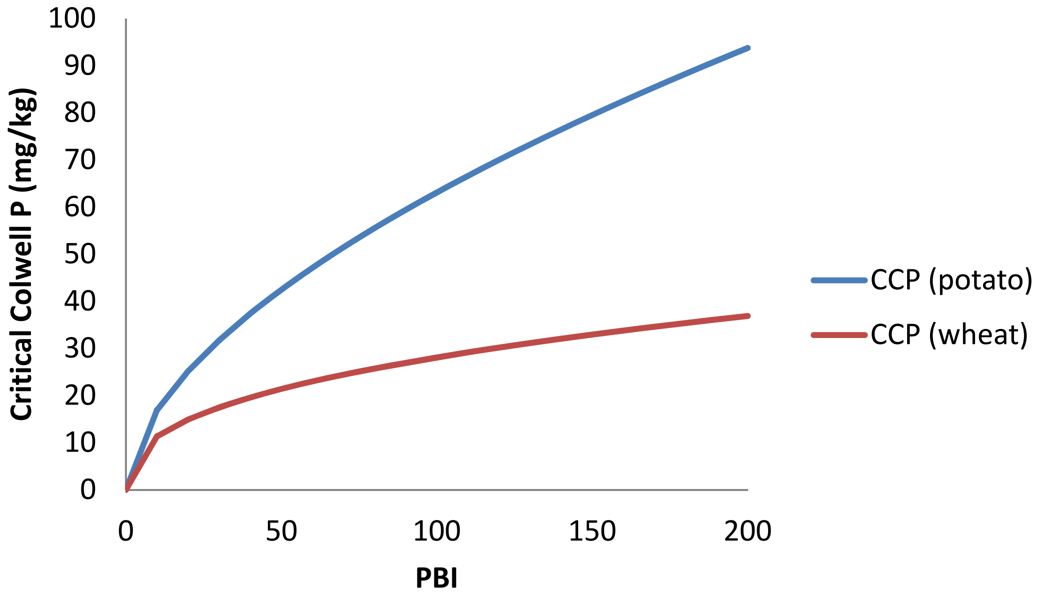

Figure 2. Relationship between buffering index (PBI) interpretation and critical Colwell P (CCP) for both wheat and potato. (Moody 2007).

Unlike the Colwell P, the DGT tests in broad acre crops have only one defined critical value as it assesses available P accurately across all soil types and is not dependent on soil type variability. No critical threshold for DGT has been developed for potato, so a threshold level was approximated using the known wheat threshold.

The DGT critical threshold for response to P in wheat is < 53 µg/L (Mason et al. 2010). The P efficiency of potato appears to be approximately half that of wheat, as at the same PBI value the critical Colwell P value for wheat is approximately half that of potato (Fig. 2). Therefore the DGT threshold could be double that of the wheat critical threshold. Using this assumption, the approximate DGT critical threshold for potato is 100 µg/L.

3.3.8 Critical value determination – potassium (K)

The critical Colwell K determined by the plateau of curves generated for potato from two separate studies (Fig. 3) is approximately 120 -200 mg/kg. The critical value is defined as the intercept of the curve relationship with 90% relative yield. No correction of Colwell K values similar to the Colwell P using PBI has been established. Therefore only the one critical value can be used for both sites.

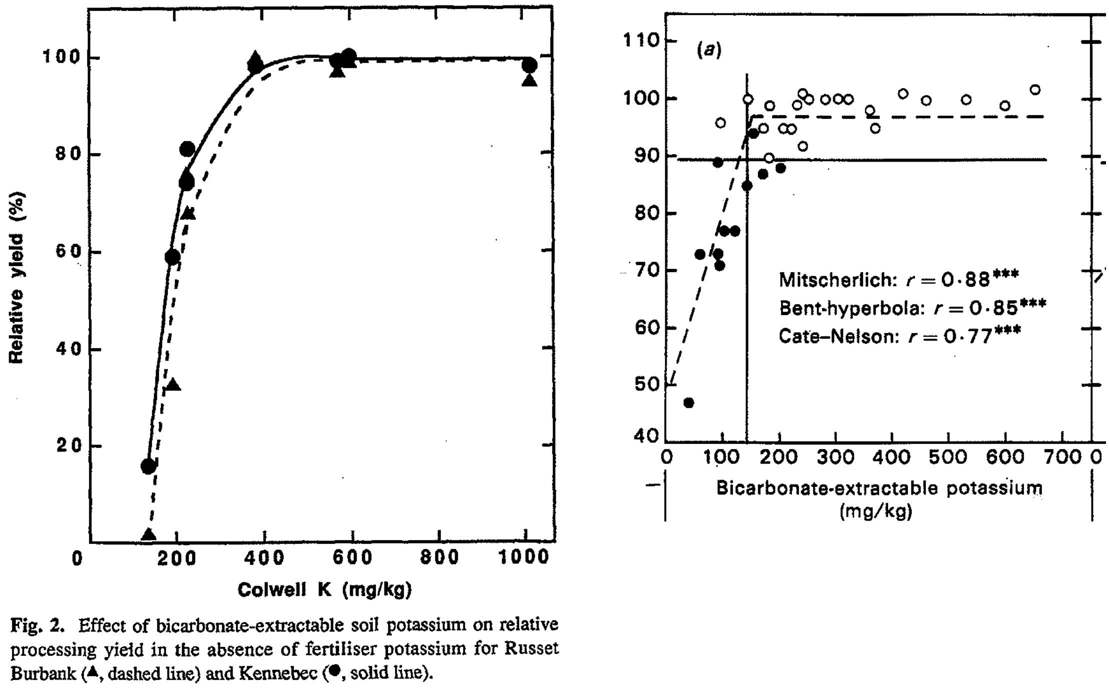

Figure 3. Graphs used to determine critical Colwell K levels, a) Chapman et al. 1992 (L), b) Maier 1986 (R).

3.4 Results – South East

3.4.1 Pre fertiliser soil tests

Reactive aluminium (Table 2), reactive iron (Table 3) and DGT magnesium (Table 4) showed a significant (F pr. < 0.05) interaction between the P and K treatment areas. Ammonium nitrogen (CSBP) and Critical Colwell P (UA) varied between phosphorous treatments (Table 5) and Colwell K, CDGT and mass potassium (UA) varied between potassium treatments (Table 6). No significant interactions were observed for any of the other measurements (Table 7).

Table 2. Reactive aluminium (mg/kg) in soil prior to treating with various levels of potassium (K) and phosphorous (P). Results from CSPB Ltd analysis. Interactions significant F pr. = 0.025, l.s.d. 294.

Reactive aluminium (mg/kg soil)					
		P (kg/ha)			
		0	50	100	200
K (kg/ha)	0	2467	2263	2182	2145
	150	2161	2199	2304	2404
	300	2708	2823	2997	2785
	600	2924	2793	2726	2421

Table 3. Reactive iron (mg/kg) in soil prior to treating with various levels of potassium (K) and phosphorous (P). Results from CSPB Ltd analysis. Interactions significant F pr. < 0.001, l.s.d. 118.

Reactive iron (mg/kg soil)					
		P (kg/ha)			
		0	**50**	**100**	**200**
K (kg/ha)	**0**	807	730	667	638
	150	654	649	699	795
	300	931	1025	1156	1042
	600	1102	988	935	820

Table 4. Mass of magnesium (µg on gel DGT) in soil prior to treating with various levels of potassium (K) and phosphorous (P). Results from University of Adelaide analysis. Interactions significant F pr. = 0.012, l.s.d. 7.3.

Mass of magnesium (µg on gel DGT)					
		P (kg/ha)			
		0	**50**	**100**	**200**
K (kg/ha)	**0**	9.2	16.0	9.0	6.7
	150	14.4	21.2	14.5	13.0
	300	13.0	12.1	22.5	15.5
	600	20.4	13.6	13.9	16.8

Table 5. Nutrients in soil prior to treating with various levels of phosphorous (P) with significant differences (F pr.<0.05). Results from CSPB Ltd and University of Adelaide (UA) analysis.

Element and (unit)	**l.s.d**	**P (kg/ha)**			
		0	**50**	**100**	**200**
Ammonium nitrogen 0-25 cm (mg/kg)	0.63	2.7	2.5	2.4	3.3
Ammonium nitrogen 25-50 cm (mg/kg)	0.5	2.4	2.2	2.8	2.8
Critical Colwell P (UA)	3.8	82.8	79.8	77.1	78.2

Table 6. Nutrients in soil prior to treating with various levels of phosphorous (P) with significant differences (F pr.<0.05). Results from University of Adelaide analysis. DGT C_{DGT} is the P measurement by DGT.

Element and (unit)	l.s.d	K (kg/ha)			
		0	150	300	600
Colwell K (mg/kg)	67	663	621	624	546
DGT C_{DGT} (µg /L)	31.9	244	242	271	281
Mass K (µg on gel DGT)	21.6	13.6	22.0	25.9	47.5

Table 7. Elements with non significant interactions (F pr. > 0.05) measured in soil prior to treating with various levels of potassium (K) and phosphorous (P). Results from CSPB Ltd or University of Adelaide (UA) analysis.

Element measured (unit)	F pr.		
	K tmt	P tmt	Interaction K & P
0-25cm Nitrate Nitrogen (mg/Kg)	0.854	0.287	0.903
25-50cm Nitrate Nitrogen (mg/Kg)	0.852	0.450	0.825
Calcium Carbonate (%)	0.207	0.176	0.588
Conductivity (dS/m)	0.359	0.574	0.991
Exc Aluminium (meq/100g)	0.913	0.972	0.982
Exc Calcium (meq/100g)	0.076	0.432	0.642
Exc Magnesium (meq/100g)	0.957	0.905	0.338
Exc Potassium (meq/100g)	0.732	0.867	0.926
Exc Sodium (meq/100g)	0.959	0.841	0.22
Total Phosphorus (mg/Kg)	0.753	0.928	0.755
pH Level (CaCl2 pH)	0.144	0.307	0.077
pH Level (H2O pH)	0.183	0.75	0.285
Phosphorus Colwell (mg/Kg)	0.819	0.618	0.567
Potassium Colwell (mg/Kg)	0.871	0.773	0.917
UA Colwell P (mg/Kg)	0.357	0.58	0.361
UA PBI	0.828	0.022	0.136
UA Mass Ca (ug on gel DGT)	0.333	0.693	0.131

When analysed with one way ANOVA, only reactive Iron and mass of Magnesium showed significant differences between the sites that were subsequently treated with fertilisers (Table 8).

Table 8. Elements measured in soil prior to treating with various levels of potassium (K) and phosphorous (P). One way ANOVA between treatments. Results from CSPB Ltd or University of Adelaide analysis.

Element	**F pr.**	**Grand mean**
CSBP Ltd		
Reactive Iron	<0.001	852 mg/kg
Ammonium Nitrogen 0-25 cm	0.527	2.7 mg/kg
Nitrate Nitrogen 0-25 cm	0.918	26.6 mg/kg
Ammonium Nitrogen 25-50 cm	0.434	2.5 mg/kg
Nitrate Nitrogen 25-50 cm	0.969	26.6 mg/kg
Exchangeable Potassium (meq/100g)	0.986	2.6 meq/100g
Potassium Colwell (mg/Kg)	0.978	757 mg/kg
Phosphorus Colwell (mg/Kg)	0.735	85.7 mg/kg
Total Phosphorus (mg/Kg)	0.921	376 mg/kg
pH Level (CaCl2)	0.169	7.3
pH Level (H_2O)	0.584	8.1
Exchangeable Aluminium	0.999	0.04 meq/100g
Exchangeable Calcium	0.469	41.8 meq/100g
Exchangeable Magnesium	0.9	7.8 meq/100g
Exchangeable Sodium	0.982	1.8 meq/100g
University of Adelaide		
Colwell K	0.243	613 mg/kg
Mass K on gel	0.156	26.2 µg
PBI	0.067	150.2
Colwell P	0.428	133.1 mg/kg
Critical Colwell P	0.083	79.49 mg/kg
DGT C_{DGT} (DGT P measurement)	0.154	259.4 µg/L
Mass Ca on gel DGT	0.528	106 µg
Mass Mg on gel DGT	0.019	14.5 µg

3.4.2 Yield

The tuber yields showed significant interactions between the various fertiliser treatments (Table 9). However there were no clear correlations with fertiliser rate and yield, with the lowest yield of 27 kg/6m row in the 200 kg/ha P and 0 K treatment and the highest yield of 39.2 kg/6m row in the treatment with 50 kg/ha P and 150 kg/ha K. Similar trends were observed in the marketable yield with the smaller tubers removed from the yields (Data not presented).

When K and P rates were combined, no response in yield was observed with any of the P application rates (Fig. 4). There was also no effect on the yield response to P with the varied potassium rates (Fig. 5).

No response to yield was observed at any of the fertiliser rates applied (Figs 6, 7). A small yield increase was observed at the 150 kg/ha rate of Potassium when all P rates were combined (Fig. 6) however the difference was not significant (P=0.07). This is possibly driven by the larger response (24% increase in yield) seen at the 50 kg/ha rate of phosphorous (Fig. 7).

The variations in the treatments that produced the lowest and highest yields suggest that a factor other than fertilisation is contributing to the significant differences. The pre-fertiliser nutrients that showed significant differences between treatments were not significant covariates (eg. total harvest weight / reactive iron cov. F pr = 0.266), indicating they were not a cause of the differences in yield.

Table 9. Yield (kg per 6m of row) from potato grown in soil treated with various levels of potassium (K) and phosphorous (P). Interactions significant F pr. <0.001, l.s.d. 5.0.

Yield kg/6m row					
		P (Kg/Ha)			
		0	**50**	**100**	**200**
K (Kg/Ha)	**0**	32.3	33.0	32.7	27.3
	150	35.8	39.2	31.7	30.7
	300	32.1	30.6	38.1	34.7
	600	30.6	32.9	29.9	35.8

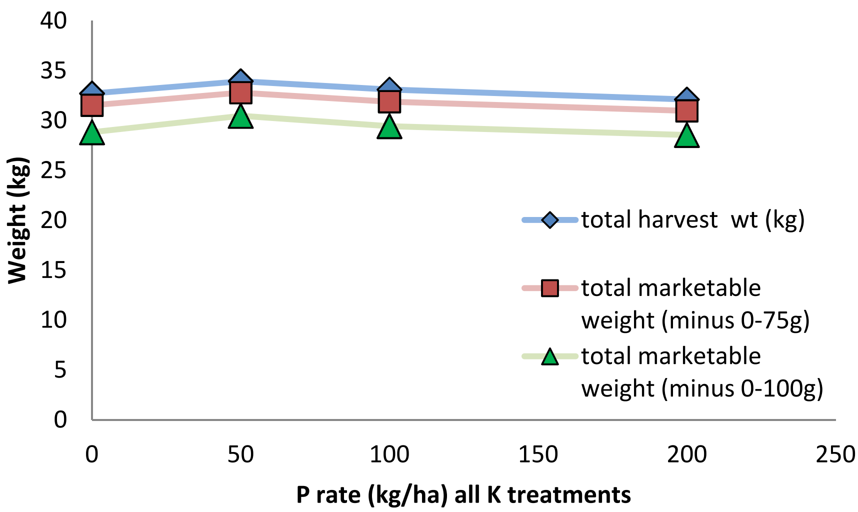

Figure 4. Yield of tubers (total, marketable tubers over 75g and marketable tubers over 100g) for all potassium (K) rates combined at various rates of phosphorous (P) applied.

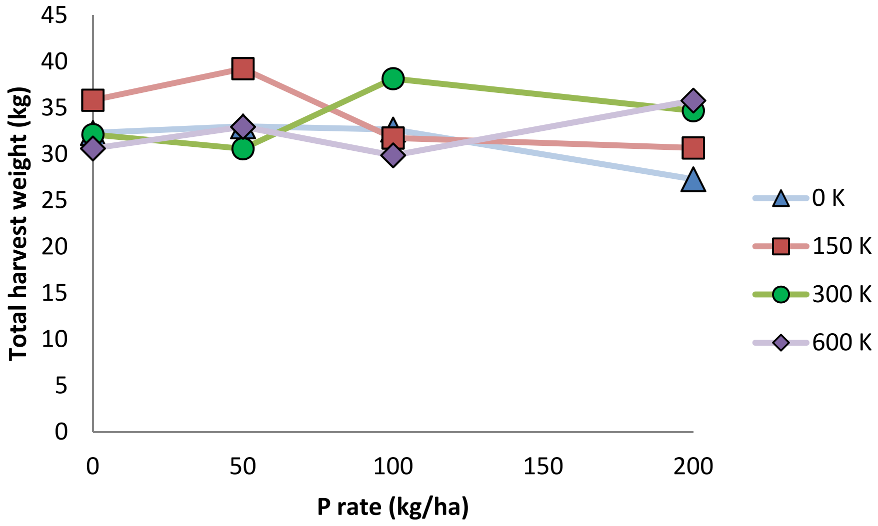

Figure 5. Total harvest weight of tubers with four rates of potassium (K) (0, 150, 300 and 600 kg/ha) and four rates of phosphorous (P) (0, 50, 100 and 200 kg/ha).

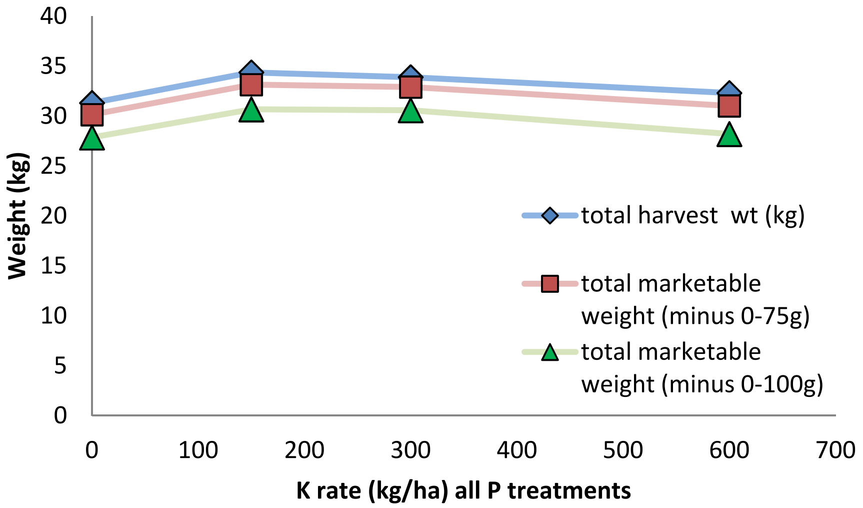

Figure 6. Yield of tubers (total, marketable tubers over 75g and marketable tubers over 100g) with various rates of potassium applied.

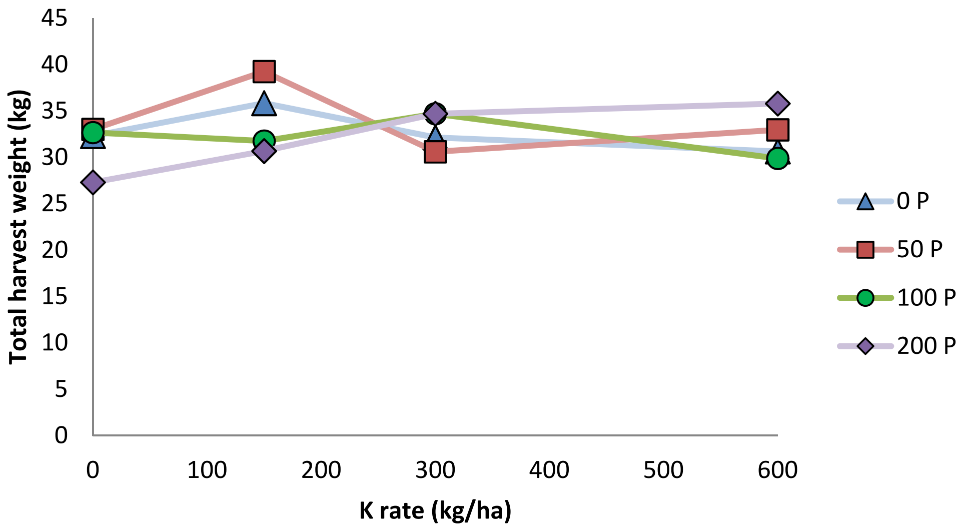

Figure 7. Total harvest weight of tubers with of four rates of phosphorous (P) (0, 50, 100 and 200 kg/ha) and four rates of potassium (K) (0, 150, 300 and 600 kg/ha).

3.4.3 Response prediction – phosphorus (P)

The mean Colwell P results from the split samples at Glenroy varied between laboratories, with CSBP result of 89 mg/kg P and the University of Adelaide result of 133 mg/kg (Table 12). All measurements varied between sites, with lower levels of P at Parilla for all measurements (Table 12).

Table 12. Soil phosphorous (P) levels at two sites (Glenroy and Parilla) determined by Colwell P test (by CSBP commercial laboratory and University of Adelaide (AU)) and DGT by the University of Adelaide.

Means	**Colwell P mg/kg (CSBP)**	**Colwell P mg/kg (UA)**	**PBI (UA)**	**Critical Colwell P**	**DGT (C_{DGT}) µg/L**
Glenroy	89	133	150	79	259
Parilla	n/a	41	13	18	123

The Colwell P at Glenroy (both CSBP and UA) and Parilla (UA only) were all greater than the critical Colwell P calculated from the PBI (Table 12). Therefore no response to P was predicted at either site.

At both Glenroy and Parilla, the DGT values (259 and 123 µg/L respectively) were higher than the approximate critical threshold of 100 µg/L. Therefore no response to P was predicted at either site.

3.4.4 *Response prediction – potassium (K)*

The potassium levels were lower at Parilla than Glenroy with Colwell K of 613 mg/kg and 80 mg/kg and DGT of 6979 µg/L and 4020 µg/L respectively (Table 13).

Table 13. Soil potassium (K) levels at two sites (Glenroy and Parilla) determined by Colwell K test (by CSBP commercial laboratory and University of Adelaide (AU)) and DGT by the University of Adelaide.

Means	Colwell K mg/kg (CSBP)	Colwell K mg/kg (UA)	DGT (C_{DGT})# µg/L
Glenroy	757	613	6979
Parilla*	n/a	80	4020

*Not harvested

#Values still need validating against crop response.

The Colwell K at Glenroy for both CSBP and UA was greater than the critical Colwell K of 120 -200 mg/kg and no response to K was predicted.

However at Parilla, the Colwell K (UA) at 80 mg/kg was lower than the critical Colwell K and therefore a response to K was predicted.

No work has looked at DGT K measurement with the response of any crop type, therefore no prediction can be made. However as the levels at Parilla were lower, that crop may be more susceptible to K deficiency compared to Glenroy.

3.5 Conclusions

The prediction from both DGT and Colwell P of “no response to P” was validated with the yield results at the one site at Glenroy.

The prediction from Colwell K of “no response to K” was validated with the yield results at the one site at Glenroy.

As no yield response was observed at Glenroy, the DGT threshold for a potato response would therefore be below the DGT value obtained of 6979 µg/L (C_{DGT}).

3.6 References

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4 TECHNOLOGY TRANSFER

- Discussions regarding preliminary soil analysis results and general project outcomes have been held with key growers and industry representatives within the South East of South Australia.
- Phosphorous and potash for the French fry industry - PIRSA Rural Solutions web site: http://www.ruralsolutions.sa.gov.au/markets/agriculture/news/phosphorous_and_potash_for_the_french_fry_industry
- A grower and industry workshop was planned at the completion of the project. Due to personnel changes this has not been possible. Outcomes of the project have been communicated to growers and industry personnel by mail and personal contact.
- Outcomes of the project were presented at a processing potato grower meeting in the South East of SA December 2011.

5 RECOMMENDATIONS

- That growers using currently available soil tests utilise the PARJIB methodology for reliable and applicable fertiliser recommendations.

- That more detailed comparisons on more replicated sites be undertaken to confirm the effectiveness of DGT for phosphorous as an alternative to the Colwell soil testing method.

- That more field trials be undertaken to support the development of the experimental DGT potassium soil test into a more reliable testing methodology.

5.1 Recommendations from Adelaide University report.

- Assess the performance of DGT and established soil testing methods utilising a greater number of field trials with contrasting soil types. This will better enable the determination of a) the benefits of DGT technology in the potato industry (production of calibration curves), b) outline if issues with the Colwell P method seen with broad acre crops can also occur with potatoes.

- Through a modified sampling program, calibration curves could be produced utilising a small number of field trials. This can be achieved by sampling soon after fertiliser rates have been applied to establish P and K levels at these application rates

5.2 Recommendations from NZ report.

Application rates of P and K should be chosen to achieve target yields that are consistent with the other management inputs that the crop receives. There is no benefit in applying sufficient P or K for the crop to achieve a high yield if N applications, irrigation, and weed or disease control are not managed sufficiently to achieve similarly high yields.

Recommended application rates of P and K to achieve target yields are provided in Tables 2 and 3, respectively. They are based on an average field bulk density of 1.3 g/cm^3 in the top 15 cm of soil (representing the average across all four trials to date). To correct fertiliser applications for different paddocks, multiply the rate by 1.3 and then divide by the actual field bulk density measured. A higher bulk density will decrease the amount of fertiliser required, whereas a lower bulk density will increase it. It is important to note that these application rates are not calculated to optimise economic returns based on current fertiliser and crop prices.

Future trials to calibrate the model further and strengthen its recommendations would benefit growers, especially on soil types that have not currently been assessed (e.g. volcanic and other clay soils). The importance of fertiliser placement practices should also be evaluated on heavier soil types that were not included in the initial work; soil characteristics at such sites may result in a crop yield benefit from banding. Growers are reminded that late-season applications of K were shown to be ineffective in earlier work.

Table 2. P applications calculated to achieve the target yield indicated by the Potato Calculator™. The recommendations are for broadcast P, given in kg of P per hectare. Assumed soil bulk density is 1.3 g/cm^3 in the top 15 cm; to correct fertiliser applications for different paddocks multiply the rate by 1.3 and then divide by the actual bulk density measured. (Copied from the NZ Report)

Colwell P (mg/kg)[1]	***Target maximum yield (fresh, in t/ha)***														
	30	***35***	***40***	***45***	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***	***100***
5	36	45	54	63	72	80	89	98	107	116	124	133	142	151	160
10	20	29	38	47	55	64	73	82	91	99	108	117	126	134	143
20	-	-	5	14	23	32	40	49	58	67	76	84	93	102	111
30	-	-	-	-	-	-	8	17	26	34	43	52	61	70	78
40	-	-	-	-	-	-	-	-	-	2	11	19	28	37	46
50	-	-	-	-	-	-	-	-	-	-	-	-	-	5	13
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1]Measured at planting, 0–15 cm.

Table 3. K applications calculated to achieve the target yield indicated by the Potato Calculator™. The recommendations are for broadcast K, given in kg of K per hectare. Assumed soil bulk density is 1.3 g/cm^3 in the top 15 cm; to correct fertiliser applications for different paddocks multiply the rate by 1.3 and then divide by the actual bulk density measured. (Copied from the NZ Report)

Exchangeable K (meq/100 g)[1]	***Comparable Colwell K (mg/kg)[1,2]***	***Target maximum yield (fresh, in***														
		30	***35***	***40***	***45***	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***	***100***
0.10	44	241	301	361	421	480	540	600	660	720	779	839	899	959	1018	1078
0.15	65	182	242	302	362	422	481	541	601	661	721	780	840	900	960	1020
0.20	85	124	184	243	303	363	423	482	542	602	662	722	781	841	901	961
0.25	105	65	125	185	244	304	364	424	484	543	603	663	723	782	842	902
0.30	124	6	66	126	186	245	305	365	425	485	544	604	664	724	783	843
0.35	142	-	7	67	127	187	246	306	366	426	486	545	605	665	725	785
0.40	161	-	-	8	68	128	188	247	307	367	427	487	546	606	666	726
0.45	178	-	-	-	9	69	129	189	249	308	368	428	488	547	607	667
0.50	195	-	-	-	-	10	70	130	190	250	309	369	429	489	549	608
0.55	212	-	-	-	-	-	11	71	131	191	251	310	370	430	490	550
0.60	228	-	-	-	-	-	-	13	72	132	192	252	311	371	431	491
0.65	244	-	-	-	-	-	-	-	14	73	133	193	253	312	372	432
0.70	259	-	-	-	-	-	-	-	-	15	74	134	194	254	314	373
0.75	274	-	-	-	-	-	-	-	-	-	16	75	135	195	255	315
0.80	289	-	-	-	-	-	-	-	-	-	-	17	76	136	196	256
0.90	317	-	-	-	-	-	-	-	-	-	-	-	-	19	79	138
1.00	345	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
1.10	371	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1]Measured at planting, 0–15 cm. [2]Calculated from a regression of exchangeable K and Colwell K values measured in these trials ($y = 27.419x^3 - 133.27x^2 + 450.39x$, where x = measured exchangeable K value, y = predicted Colwell K value; $R^2 = 0.998$).

6 APPENDICES

6.1 Adelaide University

Dr. Sean Mason, School of Agriculture, Food and Wine

6.2 NZ Plant & Food

Best management practices for phosphorus and potassium applications to potatoes grown in South Australia

Johnstone PR, Reid JB, Searle B, Peake R., August 2011, SPTS No. 5887

This report was produced in support of HAL funded project, PT10005

Improved technique for accurate prediction of soil phosphorus (P)

fertiliser requirements regardless of soil type.

This report is for the Glenroy and Parilla trial sites to assess the DGT soil test method in the potato industry.

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1 PROJECT SUMMARY

The following reports on the first known project that has assessed the performance of DGT in terms of predicting Potato responses to P. It is also the first work that has looked at using the DGT method to 1) assess K availability and 2) translate these values to a crop response, in this case potato. Therefore this work is highly innovative and could provide highly significant outcomes to the potato industry. The performance of DGT in this initial phase of work was unfortunately only assessed at one site and therefore while results appeared to predict the non response seen, this assessment is highly speculative. The Colwell P (with PBI interpretation) levels also suggested that a non response was predicted. In terms of K it is unfortunate that one of the sites was ruined by climatic conditions experienced as this is where there was a contrast between Colwell K and DGT K values between the two sites and where different interpretations of values could have occurred. However the Colwell K did correctly predict the response to K at the one site when the soil test levels are compared to other studies. Ideally it would be beneficial to test the applicability of DGT to predict P and K responses over a range of field sites to enable the development of a calibration curve and therefore establishment of DGT critical values for potatoes in regards to P and K.

2 PROJECT ACHIEVEMENTS

1) Established upper limits of DGT P and K critical values for potatoes through non-response at single site
2) Colwell P with PBI interpretation correctly predicted non response to P
3) Colwell K levels explained the non response to K applications through the use of other previous studies.

3 FUTURE REQUIREMENTS/ RECOMMENDATIONS

1) Assess the performance of DGT and established soil testing methods utilising a greater number of field trials with contrasting soil types. This will better enable the determination of a) the benefits of DGT technology in the potato industry (production of calibration curves), b) outline if issues with the Colwell P method seen with broad acre crops can also occur with potatoes.
2) Through a modified sampling program, calibration curves could be produced utilising a small number of field trials. This can be achieved by sampling soon after fertiliser rates have been applied to establish P and K levels at these application rates.

4 TECHNICAL REPORT

4.1 Introduction

Currently in Australia if phosphorus (P) deficiency is detected it is difficult to correct during the growing season and therefore the correct decision on the rate of P must be made up-front. This places greater importance on accurate soil testing and has become increasingly important, especially in recent times when tough decisions had to be made about cutting costs because of the drought. Now with better seasons farmers are requiring information on how to best manage their P levels so they don't miss out when returns are better.

Recent work utilising response trials of broad acre crops has shown that the performance of current soil testing methods most widely used to predict available P levels are poor, especially when contrasting soil types are compared (Mason et al. 2010). The data supports a general pessimism of farmers in relation to current soil tests and therefore they have adopted other systems to help maintain P fertility levels

In the same work an improved soil test for P was identified that will deliver accurate assessment of P reserves and determine if they are high enough to support crop production for the current year. This new soil test, "Diffuse Gradient in Thin Films" (DGT), assesses P availability in the soil at similar conditions to which the plant will grow at and therefore what access to P it has. Other soil test methods assess P availability in a diluted system (small amount of soil: large volume of water or extract) and for the extraction methods the P availability is measured at a set pH, which may not match the paddock pH. Both changes in soil conditions can have a large impact on the assessment of P availability and therefore not determine the actual P level in which the crop is growing. Currently the DGT soil P test has had a success rate of > 90% in predicting crop responses to P including wheat, canola, peas and barley (Mason et al. in preparation). By comparison the Colwell P with buffering index (PBI) interpretation (Moody 2007) has had a success rate of 67% for the wheat trial dataset. The PBI inclusion to correct Colwell P has not been established for the other crop types.

The success of the DGT method in predicting crop responses to P highlights its potential to extend the use of DGT results into other areas of agriculture namely vegetables and pastures. In principle accurate assessment of the amount of P available to a certain crop will enable correlations to be produced even when varying P requirements will occur depending on the crop type grown. However if a certain crop type is able to respond to low P levels by chemically solubilising other forms of P from the soil it is expected that the accuracy of DGT will reduce as the method cannot mimic these conditions induced by the crop.

4.2 Methods

Two replicated field experiments were established on commercial properties in Glenroy in the South East and Parilla in the Murryland districts of South Australia. The Parilla site was abandoned due to flooding in December and January that washed out the trial area.

Trial layout.

The 16 treatment combinations were each replicated three times and set up as a randomised complete block. Individual plots were 6 beds wide by 8 m in length, with the two outside beds designated as border rows.

Pre plant soil sampling and testing

Two soil samples were taken from each plot prior to planting. A composite sample of 30 cores at 0- 15cm using 13mm corer was collected from each plot. The sample was mixed and split, with half provided to Adelaide University for the DGT testing and half to the commercial laboratory CSBP Ltd in Western Australia for Colwell testing.

Crop details

Potato seed cv. 'Russet Burbank' was planted on 20 October 2010 and irrigated by centre pivot as per normal grower practice. All plots received the same N fertiliser rate (310 kg N/ha), which was determined using the Potato Calculator^{TM} (www.croplogic.com) and grower experience to ensure N was not limiting. Applications were split-applied as solid urea (100 kg N/ha) at 28 days after planting (DAP) followed by fertigation with liquid N in each irrigation (approximately 6.4 kg N/ha on each occasion). The crop was harvested on 30 March 2011.

Fertiliser treatments

Four rates of P fertiliser (P0, P0.5, P1 and P2) and four rates of K fertiliser (K0, K0.5, K1 and K2) were combined in a factorial design to create a range of soil P and K supply levels (Table 1). These rates reflected 0, 50, 100 and 200% of the growers' standard P and K practice at the site.

All P was applied as single super (8.8%P), while K was applied as sulfate of potash (41% K). Treatments were applied 28 DAP, with the exception of the K2 rate, which was split-applied (50 : 50) at 28 DAP and 59 DAP to avoid any potential toxicity effect on the crop. All applications were surface broadcast.

Table 1. Summary of P and K fertiliser application rates at the Glenroy trial site, 2010–11.

P fertiliser application rate (kg P/ha)				*K fertiliser application rate (kg K/ha)*			
P0	*P0.5*	*P1*[1]	*P2*	*K0*	*K0.5*	*K1*[1]	*K2*
0	50	100	200	0	150	300	600

[1]P1 and K1 reflected the standard grower practice at the trial site. All plots received 310 kg N/ha.

Crop measurements

Potato yields were measured in each individual plot at commercial maturity (161 DAP). Tubers were dug from the middle 2m of each row from the centre three beds. Tubers were graded into five size categories (0–75 g, 75–100 g, 100–170 g, 170–340 g, >340 g), counted and weighed fresh. A 3.5 kg composite sample (tubers above 75 g) from each treatment was oven-drying at 75ºC for 7 days to estimate percent dry matter (DM).

Critical value determination – phosphorous (P)

The Critical Colwell P, the level above which no response to additional P is predicted, was calculated using the buffering index (PBI) interpretation of Moody (2007) (Fig. 1).

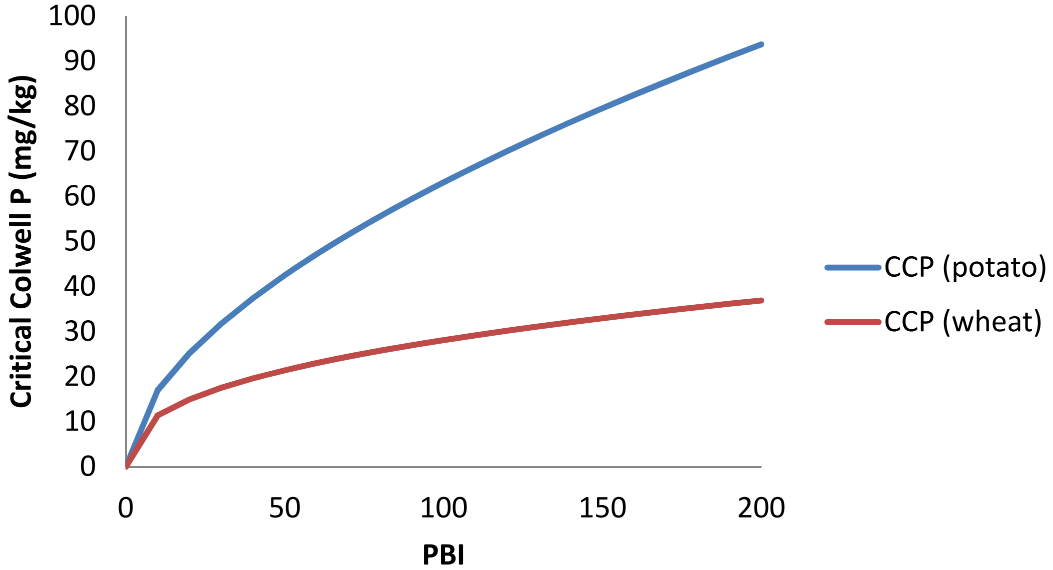

Figure 1. Relationship between buffering index (PBI) interpretation and critical Colwell P (CCP) for both wheat and potato. (Moody 2007).

Unlike the Colwell P, the DGT tests in broad acre crops have only one defined critical value as it assesses available P accurately across all soil types and is not dependent on soil type variability. No critical threshold for DGT has been developed for potato, so a threshold level was approximated using the known wheat threshold.

The DGT critical threshold for response to P in wheat is < 53 µg/L (Mason et al. 2010). The P efficiency of potato appears to be approximately half that of wheat, as at the same PBI value the critical Colwell P value for wheat is approximately half that of potato (Fig. 1). Therefore the DGT threshold could be double that of the wheat critical threshold. Using this assumption, the approximate DGT critical threshold for potato is 100 µg/L.

Critical value determination – potassium (K)

The critical Colwell K determined by the plateau of curves generated for potato from two separate studies (Fig. 2) is approximately 120 -200 mg/kg. The critical value is defined as the intercept of the curve relationship with 90% relative yield. No correction of Colwell K values similar to the Colwell P using PBI has been established. Therefore only the one critical value can be used for both sites.

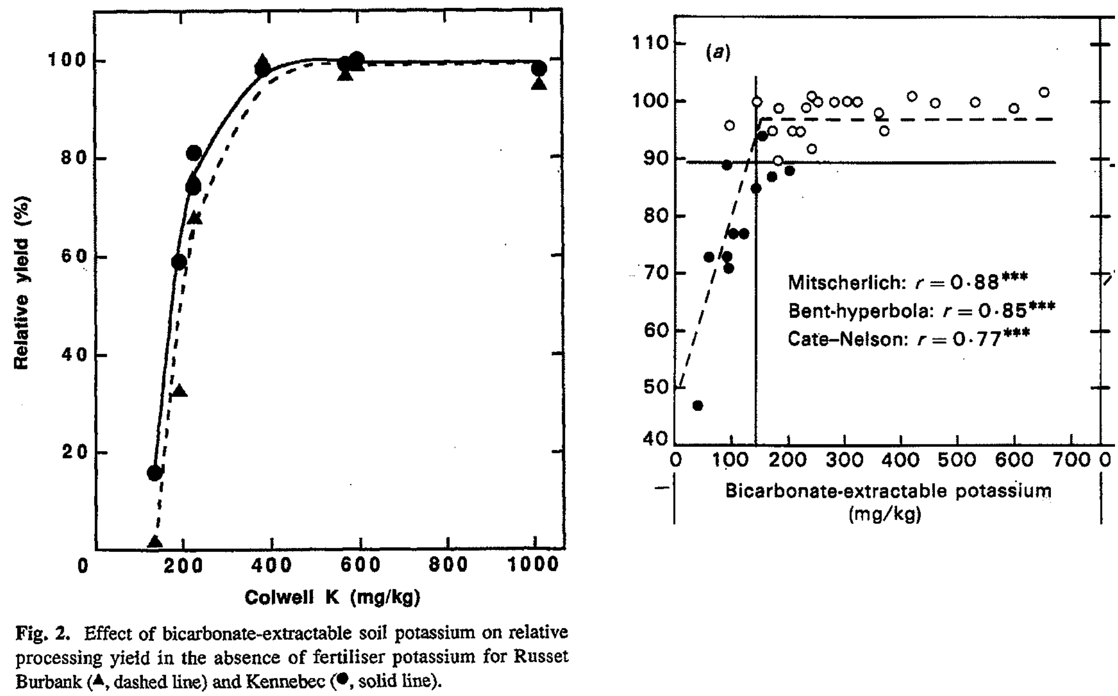

Figure 2. Graphs used to determine critical Colwell K levels, a) Chapman et al. 1992 (L), b) Maier 1986 (R).

4.3 Results

4.3.1 Phosphorus

The Colwell P results from the split samples at Glenroy varied between laboratories, with CSBP result of 89 mg/kg Phosphorous and the University of Adelaide result of 133 mg/kg (Table 2). All measurements varied between sites, with lower levels of P at Parilla for all measurements (Table 2).

Table 2. Soil phosphorous (P) levels at two sites (Glenroy and Parilla) determined by Colwell P test (by CSBP commercial laboratory and University of Adelaide (AU)) and DGT by the University of Adelaide.

Means	**Colwell P mg/kg (CSBP)**	**Colwell P mg/kg (UA)**	**PBI (UA)**	**Critical Colwell P**	**DGT (C_{DGT}) µg/L**
Glenroy	89	133	150	79	259
Parilla	n/a	41	13	18	123

Response prediction (Colwell P)

The Colwell P at Glenroy (both CSBP and UA) and Parilla (UA only) were all greater than the critical Colwell P calculated from the PBI (Table 2). Therefore no response to P was predicted at either site.

Response predictions (DGT)

At both Glenroy and Parilla, the DGT values (259 and 123 µg/L respectively) were higher than the approximate critical threshold of 100 µg/L. Therefore no response to P was predicted at either site.

Yield results (Glenroy)

No response in yield was observed at Glenroy with any of the P application rates (Fig. 3). There was also no effect on the yield response to P with the varied potassium rates (Fig. 4).

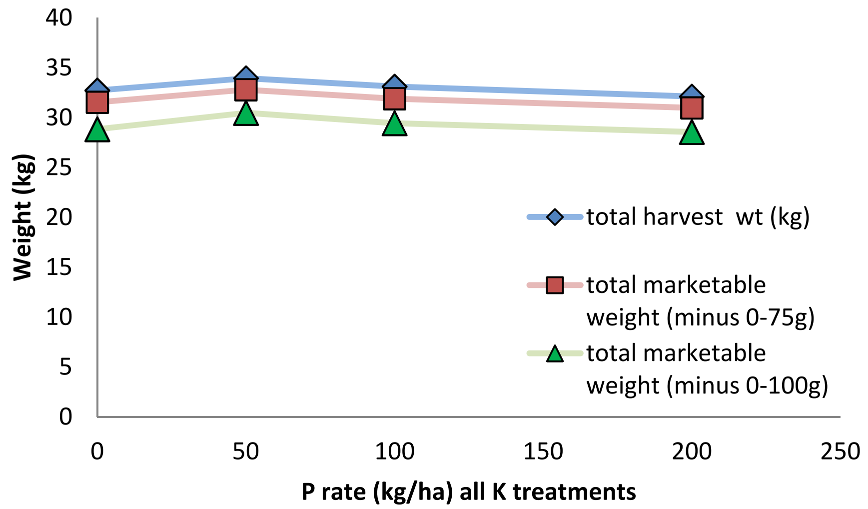

Figure 3. Yield of tubers (total, marketable tubers over 75g and marketable tubers over 100g) for all potassium (K) rates combined at various rates of phosphorous (P) applied.

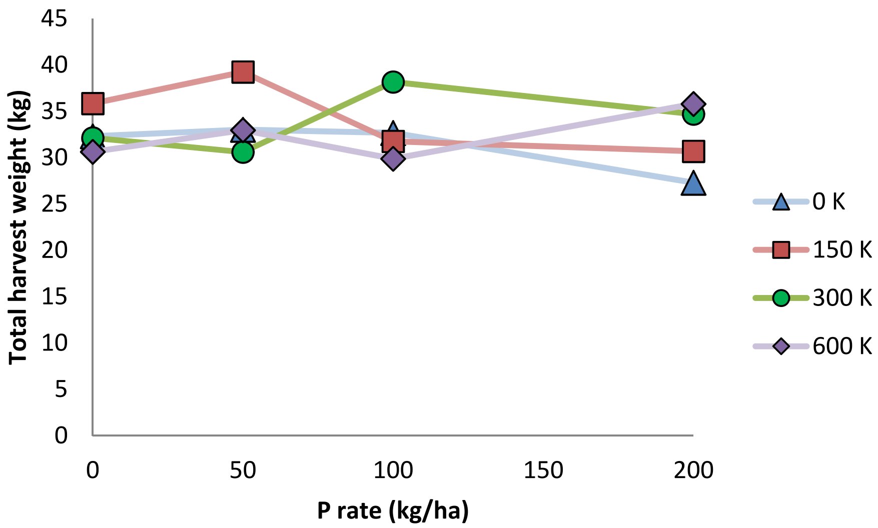

Figure 4. Total harvest weight of tubers with four rates of potassium (K) (0, 150, 300 and 600 kg/ha) and four rates of phosphorous (P) (0, 50, 100 and 200 kg/ha).

4.3.2 Potassium

The potassium levels were lower at Parilla than Glenroy with Colwell K of 613 mg/kg and 80 mg/kg and DGT of 6979 µg/L and 4020 µg/L respectively (Table 3).

Table 3. Soil potassium (K) levels at two sites (Glenroy and Parilla) determined by Colwell K test (by CSBP commercial laboratory and University of Adelaide (AU)) and DGT by the University of Adelaide.

Means	Colwell K mg/kg (CSBP)	Colwell K mg/kg (UA)	DGT (C_{DGT})# µg/L
Glenroy	757	613	6979
Parilla*	n/a	80	4020

*Not harvested

#Values still need validating against crop response.

Response prediction (Colwell K)

The Colwell K at Glenroy for both CSBP and UA was greater than the critical Colwell K of 120 -200 mg/kg and no response to K was predicted.

However at Parilla, the Colwell K (UA) at 80 mg/kg was lower than the critical Colwell K and therefore a response to K was predicted.

Response prediction (DGT)

No work has looked at DGT K measurement with the response of any crop type, therefore no prediction can be made. However as the levels at Parilla were lower, that crop may be more susceptible to K deficiency compared to Glenroy.

Yield results (Glenroy)

No response to yield was observed at any of the fertiliser rates applied (Figs 5, 6). A small yield increase was observed at the 150 kg/ha rate of Potassium when all P rates were combined (Fig. 5) however the difference was not significant (P=0.07). This is possibly driven by the larger response (24% increase in yield) seen at the 50 kg/ha rate of phosphorous (Fig. 6).

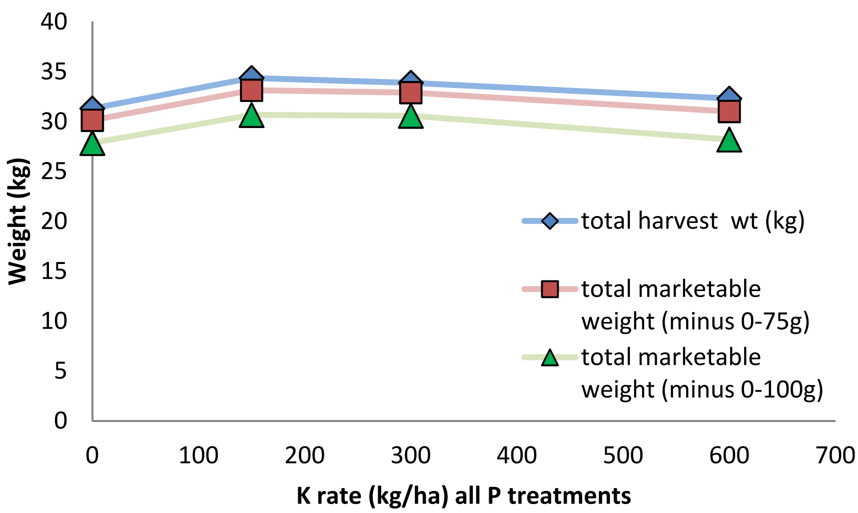

Figure 5. Yield of tubers (total, marketable tubers over 75g and marketable tubers over 100g) with various rates of potassium applied.

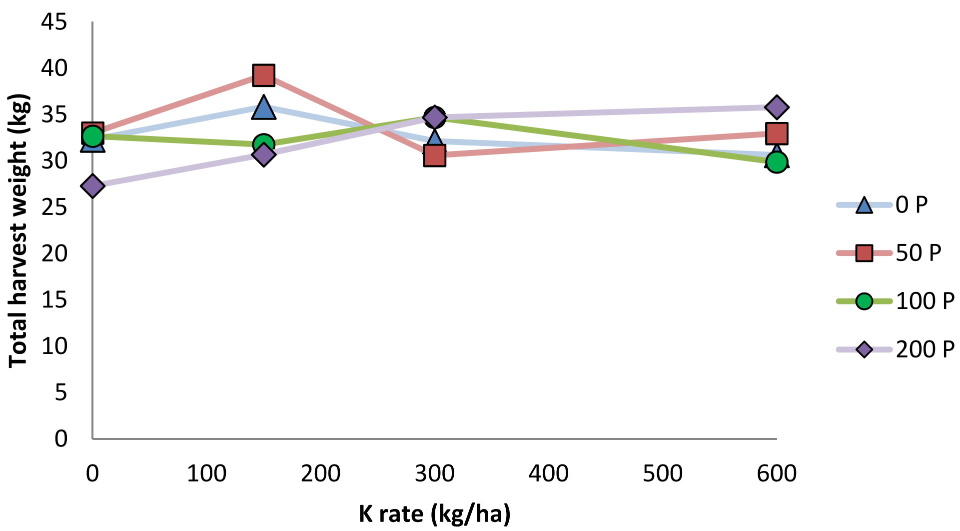

Figure 6. Total harvest weight of tubers with of four rates of phosphorous (P) (0, 50, 100 and 200 kg/ha) and four rates of potassium (K) (0, 150, 300 and 600 kg/ha).

4.4 Conclusions

The prediction from both DGT and Colwell P of “no response to P” was validated with the yield results at the one site at Glenroy.

The prediction from Colwell K of “no response to K” was validated with the yield results at the one site at Glenroy.

As no yield response was observed at Glenroy, the DGT threshold for a potato response would therefore be below the DGT value obtained of 6979 µg/L (C_{DGT}).

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Moody PW (2007) Interpretation of a single point P buffering index for adjusting critical levels of the Colwell soil P test. Soil Research 45:55-62.

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Best management practices for phosphorus and potassium applications to potatoes grown in South Australia

Johnstone PR, Reid JB, Searle B, Peake R

August 2011

A report prepared for

South Australian Research and Development Institute (SARDI)

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SPTS No. 5887

This report has been prepared by The New Zealand Institute for Plant & Food Research Limited (Plant & Food Research), which has its Head Office at 120 Mt Albert Rd, Mt Albert, Auckland.

This report has been approved by:

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Steve Thomas
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Date: 10 August 2011

Contents

1 Executive summary

Best management practices for phosphorus and potassium applications to potatoes grown in South Australia

Johnstone PR, Reid JB, Searle B, Peake R., August 2011, SPTS No. 5887

There has been little information available to help growers determine the optimal phosphorus (P) and potassium (K) fertiliser requirements of potatoes grown for processing in the South-East region of South Australia (SA). The standard practice in this area has been to apply approximately 75–150 kg P/ha and 200–300 kg K/ha, while an average yielding crop of 50 t/ha removes approximately 25 kg P and 250 kg K/ha in the tubers. The implications are that current P rates may be too high and K rates may be too low.

The aim of this project was to provide growers with robust quantitative advice on P and K management practices in this region, primarily through fitting and then applying the PARJIB model for crop responses to nutrient supply. PARJIB has been used previously by researchers to interpret nutrition experiments across a wide range of field conditions and environments.

Three P x K nutrition trials were established in commercial potato fields in the South-East region (Penola West, Mingbool and Kalangadoo) of SA during 2007–08. Results from those trials were analysed and presented in an earlier report to growers (Johnstone et al. 2008). In 2010–11 two further trials were established at Glenroy and Parilla in order to refine the model, particularly for sites where soil P and K levels were already quite high. The trial at Parilla was abandoned due to two severe rainstorm events that washed away most plots. At all sites the crops were managed according to the grower’s standard practice, with the exception of fertiliser applications in the trial area. In most, but not all, experimental treatments were designed to apply nitrogen (N) fertiliser at rates that would prevent N availability from limiting yields. At all sites P and K fertiliser were combined factorially to create a range of soil nutrient supply treatments. Background soil fertility levels also varied across sites. A variety of soil and crop measurements were made in order to calibrate the PARJIB model and subsequently to guide the development of fertiliser recommendations for growers.

Total fresh yields averaged 56.0, 70.4, 55.5 and 64 t/ha at Penola West, Mingbool, Kalangadoo and Glenroy, respectively, of which approximately 76% was in the target tuber size range (100–340 g). These represented typical yields for each growing region and season. The average dry matter (%DM) contents of tubers were 20, 21, 20, and 20% at the four sites, respectively, which were all within the accepted range (18–25% DM).

The PARJIB model fitted the combined dataset from the previous and new experiments well. The root mean square (RMS) error of calibration was 0.981 t DM/ha (7.2%). The model accounted for 79% of the observed variation in tuber DM yield. These represent improvements to the initial calibration made at the conclusion of the 2007–08 trials.

PARJIB predicted no yield response to P fertiliser unless soil P levels were low. When Colwell P values in the soil are low (~10 mg P/kg) the model forecasts that there would be positive yield responses to modest P fertiliser applications for well managed crops. There was no evidence to suggest that yield may decrease significantly if too much P fertiliser was applied.

PARJIB predicted clear yield benefits from K fertiliser within the range of soil exchangeable K found in the previous experiments (0.12–0.48 meq/100 g), but no clear response in the new trial (2.63 meq/100 g). The model generally indicates quite gentle rises in yield as K fertiliser rate increases beyond about 350 kg K/ha, and predicts that the amounts of K required to achieve maximum yield potentials can be very large. Larger applications may not be economically justified even if forecast yield appears to rise.

A series of recommendations in the form of look-up tables were developed from the model to help growers determine optimal P and K fertiliser application rates that reconcile initial soil nutrient supply and the target yield potential in a given field. These are summarised in Section 2 of this report.

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2 Recommendations

Application rates of P and K should be chosen to achieve target yields that are consistent with the other management inputs that the crop receives. There is no benefit in applying sufficient P or K for the crop to achieve a high yield if N applications, irrigation, and weed or disease control are not managed sufficiently to achieve similarly high yields.

Recommended application rates of P and K to achieve target yields are provided in Tables 1 and 2, respectively. They are based on an average field bulk density of 1.3 g/cm^3 in the top 15 cm of soil (representing the average across all four trials to date). To correct fertiliser applications for different paddocks, multiply the rate by 1.3 and then divide by the actual field bulk density measured. A higher bulk density will decrease the amount of fertiliser required, whereas a lower bulk density will increase it. It is important to note that these application rates are not calculated to optimise economic returns based on current fertiliser and crop prices.

Future trials to calibrate the model further and strengthen its recommendations would benefit growers, especially on soil types that have not currently been assessed (e.g. volcanic and other clay soils). The importance of fertiliser placement practices should also be evaluated on heavier soil types that were not included in the initial work; soil characteristics at such sites may result in a crop yield benefit from banding. Growers are reminded that late-season applications of K were shown to be ineffective in earlier work.

Table 1. P applications calculated to achieve the target yield indicated by the Potato Calculator™. The recommendations are for broadcast P, given in kg of P per hectare. Assumed soil bulk density is 1.3 g/cm^3 in the top 15 cm; to correct fertiliser applications for different paddocks multiply the rate by 1.3 and then divide by the actual bulk density measured.

Colwell P (mg/kg)[1]	***Target maximum yield (fresh, in t/ha)***														
	30	***35***	***40***	***45***	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***	***100***
5	36	45	54	63	72	80	89	98	107	116	124	133	142	151	160
10	20	29	38	47	55	64	73	82	91	99	108	117	126	134	143
20	-	-	5	14	23	32	40	49	58	67	76	84	93	102	111
30	-	-	-	-	-	-	8	17	26	34	43	52	61	70	78
40	-	-	-	-	-	-	-	-	-	2	11	19	28	37	46
50	-	-	-	-	-	-	-	-	-	-	-	-	-	5	13
60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1]Measured at planting, 0–15 cm.

Table 2. K applications calculated to achieve the target yield indicated by the Potato Calculator™. The recommendations are for broadcast K, given in kg of K per hectare. Assumed soil bulk density is 1.3 g/cm^3 in the top 15 cm; to correct fertiliser applications for different paddocks multiply the rate by 1.3 and then divide by the actual bulk density measured.

Exchangeable K (meq/100 g) [1]	***Comparable Colwell K (mg/kg)*** [1,2]	***Target maximum yield (fresh, in t/ha)***														
		30	***35***	***40***	***45***	***50***	***55***	***60***	***65***	***70***	***75***	***80***	***85***	***90***	***95***	***100***
0.10	44	241	301	361	421	480	540	600	660	720	779	839	899	959	1018	1078
0.15	65	182	242	302	362	422	481	541	601	661	721	780	840	900	960	1020
0.20	85	124	184	243	303	363	423	482	542	602	662	722	781	841	901	961
0.25	105	65	125	185	244	304	364	424	484	543	603	663	723	782	842	902
0.30	124	6	66	126	186	245	305	365	425	485	544	604	664	724	783	843
0.35	142	-	7	67	127	187	246	306	366	426	486	545	605	665	725	785
0.40	161	-	-	8	68	128	188	247	307	367	427	487	546	606	666	726
0.45	178	-	-	-	9	69	129	189	249	308	368	428	488	547	607	667
0.50	195	-	-	-	-	10	70	130	190	250	309	369	429	489	549	608
0.55	212	-	-	-	-	-	11	71	131	191	251	310	370	430	490	550
0.60	228	-	-	-	-	-	-	13	72	132	192	252	311	371	431	491
0.65	244	-	-	-	-	-	-	-	14	73	133	193	253	312	372	432
0.70	259	-	-	-	-	-	-	-	-	15	74	134	194	254	314	373
0.75	274	-	-	-	-	-	-	-	-	-	16	75	135	195	255	315
0.80	289	-	-	-	-	-	-	-	-	-	-	17	76	136	196	256
0.90	317	-	-	-	-	-	-	-	-	-	-	-	-	19	79	138
1.00	345	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
1.10	371	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1]Measured at planting, 0–15 cm. [2]Calculated from a regression of exchangeable K and Colwell K values measured in these trials ($y = 27.419x^3 - 133.27x^2 + 450.39x$, where x = measured exchangeable K value, y = predicted Colwell K value; $R^2 = 0.998$).

3 Introduction

There has been limited information available to help growers determine the optimal phosphorus (P) and potassium (K) fertiliser requirements of potatoes grown for processing in the South-East region of South Australia (SA). The standard practice in this area has been to apply approximately 75–150 kg P/ha and 200–300 kg K/ha (Frost, pers. comm. 2007). For comparison, an average yielding potato crop of 50 t FW/ha removes about 25 kg P and 250 kg K/ha in the tubers; the implications are that current P rates may be too high and K rates may be too low. To maximise profit and minimise potential environmental risks, growers sought robust recommendations that allow them to consistently predict when extra fertiliser is required and at what rate.

In 2007 three P x K nutrition experiments were undertaken to generate these recommendations for the region, primarily through fitting and then applying the PARJIB model for crop responses to nutrient supply (Project reference: HAL PT10005). The PARJIB approach has been previously used to optimise P and K fertiliser supply in a range of annual crops (Jamieson et al. 2001; Reid et al. 2002; Reid et al. 2004a, b), including potatoes grown in New Zealand soils. A key feature of the PARJIB approach is that crop responses to fertiliser depend upon the total supply of nutrients from fertilisers as well as from the soil. Both total nutrient supply and the crop yield are then scaled and expressed relative to the maximum yield that the crop could achieve without the nutrient limitation. This scaling is essential because a crop with a low yield potential will respond differently to nutrient availability than a crop with a high yield potential. Using this modelling approach also removes site and seasonal limitations that are often associated with traditional fertiliser response trials. For full details on PARJIB theory and application refer to the summary paper provided by Reid (2002).

The PARJIB model was successfully fitted to the dataset from the three P x K nutrition experiments conducted in SA, accounting for 75% of the observed variation in tuber DM yield. The key observations from these experiments were:

- PARJIB predicted no yield response to P fertiliser unless soil P levels were low (< 10 mg/kg Colwell P), at which point the model forecasts that there would be positive yield responses to P fertiliser for well managed crops (i.e. those with high yield potentials). However, at very high soil test P levels yield may decrease if too much P fertiliser is applied (this observation was preliminary and needed further testing).

- PARJIB predicted yield responses to K fertiliser across the range of soil exchangeable K levels found in these experiments (0.12–0.48 meq/100 g). The model indicated gradual increases in yield as the K fertiliser rate exceeded 350 kg K/ha, and the forecast amounts of K required to achieve maximum yield potentials can be very large. It was unlikely that these very high rates were economically justified.

A series of recommendations in the form of look-up tables were developed from the dataset to help growers select optimal P and K fertiliser rates. These accounted for initial soil nutrient supply and the target yield potential in a given field. Results were well received by growers in the region, and further experiments on additional soil types were requested to strengthen the model calibration and recommendations from it. In particular, there was interest in soils that had medium to high fertility levels.

This current report describes findings from the latest trials conducted in the South-East region of SA in 2010–11. Complete details and discussion of the results from the earlier trials can be found in the report by Johnstone et al. (2008).

4 Aim

The aim of this project was to provide growers with quantitative advice on optimal P and K fertiliser management of potatoes grown in the South-East region of SA, primarily through fitting and then applying the PARJIB nutrient forecasting model. In particular, new experiments were designed to strengthen and validate the previous model predictions across a broader range of production conditions.

5 Method

5.1 Background

In 2007–08 three trials were conducted in the South-East region (Penola West, Mingbool and Kalangadoo) of SA to quantify optimum P and K supply in potatoes. To strengthen and validate recommendations from these trials, two further experiments were undertaken in the same region in 2010–11. The new trials were on different soil types, and were selected to cover medium to high background soil fertility levels. A similar experimental approach was taken to the earlier trials, including the use of the PARJIB nutrient forecasting model to interpret field data. With the exception of fertiliser rates, all crop management was carried out by the grower using standard practice for the area.

5.2 Site and crop details

There were initially two experimental sites, one each in Parilla (medium background soil fertility) and Glenroy (high background soil fertility). Severe rainstorm events in December (110 mm in 48 h) and again in January (145 mm in 48 h) washed out most plots at Parilla and the trial had to be abandoned. The soil type at the Glenroy site was black clay, with stones at 60 cm. The plant available water holding capacity in the top 60 cm was approximately 4 cm. No N, P or K base fertilisers were applied to the trial area, which was prepared using full cultivation practices.

Potato seed (cv. 'Russet Burbank') was planted on 20 October 2010. The planting population was 34,884 seed potatoes per hectare, arranged in 0.86 m wide beds. Irrigation was applied on a regular basis by centre pivot, and totalled 833 mm across the growing season. A summary of the nutrient content of irrigation water is provided in Appendix I. Of note, large amounts of chloride (2160 kg/ha) and sodium (1080 kg/ha) were applied in the irrigation water. All plots received the same N fertiliser rate (310 kg N/ha), which was determined using the Potato Calculator™ (www.croplogic.com) and grower experience to ensure N was not limiting. Applications were split-applied as solid urea (100 kg N/ha) at 28 days after planting (DAP) followed by fertigation with liquid N in each irrigation (approximately 6.4 kg N/ha on each occasion). P and K applications are described in Section 5.3 according to the various treatment regimes. The crop was harvested on 30 March 2011.

5.3 P and K fertiliser treatments

Four rates of P fertiliser (P0, P0.5, P1 and P2) and four rates of K fertiliser (K0, K0.5, K1 and K2) were combined in a factorial design to create a range of soil P and K supply levels. These rates reflected 0, 50, 100 and 200% of the growers' standard P and K practice at the site. A summary of the actual fertiliser rates applied is provided in Table 3. All P was applied as single super (8.8%P), while K was applied as sulfate of potash (41% K). Treatments were applied 28 DAP, with the exception of the K2 rate, which was split-applied (50 : 50) at 28 DAP and 59 DAP to avoid any potential toxicity effect on the crop. All applications were surface broadcast based on findings from the previous study that indicated no measurable effect of fertiliser placement (Johnstone et al. 2008).

The 16 treatment combinations were each replicated three times, giving a total of 48 plots. Experimental design was a randomised complete block. Individual plots were 6 beds wide by 8 m in length, with the two outside beds designated as border rows. A full description of all treatment combinations including application rate and timing is provided in Appendix II.

Table 3. Summary of P and K fertiliser application rates at the Glenroy trial site, 2010–11.

P fertiliser application rate (kg P/ha)				***K fertiliser application rate (kg K/ha)***			
P0	*P0.5*	*P1*[1]	*P2*	*K0*	*K0.5*	*K1*[1]	*K2*
0	50	100	200	0	150	300	600

[1]P1 and K1 reflected the standard grower practice at the trial site. All plots received 310 kg N/ha.

5.4 Soil and crop measurements

Initial soil nutrient status was determined in each individual plot at planting. Basic soil test indicators (including soil pH, Colwell P, Colwell K, exchangeable cations, conductivity) were measured on a composite sample of 15–20 cores per plot (sampling depth was 0–15 cm). Soil mineral N was measured on a composite sample of 4 cores per plot (sampling depth was 0–25 cm and 25–50 cm). All analyses were performed using standard procedures by a commercial laboratory (CSBP Ltd, Western Australia).

Potato yields were measured in each individual plot at commercial maturity (161 DAP). The harvested area was three beds wide by 2 m long (5.16 m^2). Outside border rows in each plot were avoided. Tubers were subsequently graded into five size categories (0–75 g, 75–100 g, 100–170 g, 170–340 g, >340 g), counted and weighed fresh. A 3.5 kg composite sample (tubers above 75 g) from each treatment was used to estimate dry matter (DM) content, which was determined after oven-drying at 70ºC until a constant mass was reached.

5.5 Data analysis

Analysis of variance (ANOVA)

Yield results were initially analysed using ANOVA procedures to identify crop responses to P and K fertiliser supply at the Glenroy site. These procedures were performed using a 4 x 4 factorial analysis (four rates of P and four rates of K supply). Background soil Colwell P and exchangeable K levels in each plot were initially used as a covariate for this analysis to address potential plot to plot variation in nutrient supply. However, in all instances there was no added benefit of the covariates so they were subsequently excluded. In accordance with standard statistical practice, treatment effects with a P value < 0.05 were considered significant. Least significant difference (LSD, $\alpha = 0.05$) values were provided to separate treatment means. Treatment effects with a P value of 0.05–0.10 were recorded, but are only considered weakly significant. P values > 0.10 were considered not significant. Percentage data describing the distribution of tuber sizes were initially analysed using arcsin (angular) transformation. However, this did not affect the outcome of these analyses, so the original data are presented.

PARJIB fitting and analysis

Data collected from the previous three trials at Penola West, Mingbool and Kalangadoo were combined with the new data from the Glenroy trial in order to strengthen the PARJIB model. The original intention was to use results from each individual plot. However, this was not possible as information on some important inputs from the earlier trials (such as soil N and maximum yield) was only available at site, replicate or treatment levels. Hence the model was fitted using information pooled at the level of individual treatments at each site. In total there were 52 data points for model fitting across the four sites. The additional precision in the field data that arose from using the treatment means also improved the calibration process.

As previously described, PARJIB scaled nutrient supply by relating it to Y_{max}, which is the maximum yield that could be achieved at each site without nutrient limitation. This step is important as it enables direct comparisons of fertiliser responses for crops at different sites experiencing different weather. Usually Y_{max} is taken to be the potential yield at a standard plant population, and within the model this is adjusted for water stress and actual plant population before being used to scale the supply of N, P and K. In the three earlier trials this process was able to be simplified; Y_{max} was estimated using the Potato Calculator™ after inputting the observed amounts and distribution of mineral N in the soil at each site at planting, and then the actual amounts and timing of N fertilisers and irrigation. Estimates of yield from the Potato Calculator™ did not appear to be reliable for the Glenroy trial. Hence, a different and more conservative fitting procedure was necessary. For each site, Y_{max} was taken to be the yield of the best performing experimental treatment, and the N inputs were taken to be the initial mineral N in the top 15 cm soil plus the amounts added as fertiliser. Importantly, soil N status at all these sites was very high (for instance at Glenroy the combined soil and fertiliser total was approximately 471 kg N/ha), and the crops received regular irrigation on top of rainfall throughout the season. Neither drought nor N supply was likely to be limiting in these trials, except for a few treatments from the 2007–08 trials where N fertiliser rates were deliberately reduced to enable the effects to be compared with standard industry practice.

The PARJIB fitting process was undertaken using a genetic algorithm technique that identified the combination of parameter values that gave the smallest root mean square (RMS) error when the simulated yield values were compared with those actually observed. Once the best fit was obtained, the model was used to calculate the amounts of P and K fertilisers that would be required to achieve various Y_{max} values across a range of soil test values. Calculated values were tabulated so that growers could look up the recommendations.

6 Results and discussion

6.1 General site observations

Reasonable growth conditions were reported at the Glenroy site during the season, with mild weed and disease pressures. Seasonal rainfall totalled 374 mm. Average air temperatures were 16.1, 17.6, 19.5, 19.1 and 16.3°C in November, December, January, February and March, respectively. Average radiation levels during the same period were 24, 28, 28, 23 and 19 MJ/m^2, respectively. A full summary of seasonal weather data from the closest monitoring station (6 km from the trial site) is provided in Appendix III.

6.2 Initial soil characteristics

Initial soil fertility characteristics at the Glenroy site are summarised in Table 4. Soil pH was alkaline, reflecting the calcareous nature (high carbonate concentration) of the soil. Soil mineral N levels were high (equivalent to 132–206 kg N/ha in the top 50 cm prior to N fertiliser application), most of which was present at nitrate-N (approximately 91% of all mineral N). Soil P and K indicators were generally higher than those found in the previous three trials at Penola West, Mingbool and Kalangadoo (average Colwell P values ranged from 13 to 68 mg/kg and average exchangeable K values from 0.16 to 0.39 meq/100 g at these three sites). These differences appeared to represent the intrinsic characteristics of the clay soil at Glenroy as well as historical fertiliser and crop management practices. It is noteworthy that soil P at Glenroy was well above levels where a crop response was previously predicted by the PARJIB model (< 10 mg/kg Colwell P), making the site ideal for assessing any negative effect of very high P supply on crop yields. The high soil K levels were also ideal for testing the earlier PARJIB prediction that high K supply was necessary to maximise crop yields.

Table 4. Soil fertility at planting (0–15 cm, unless otherwise specified) at the Glenroy trial site, 2010–11.

Soil fertility indicator	***Initial value[1]***
Soil pH ($CaCl_2$)	7.3 (7.1–7.6)
Soil pH (water)	8.1 (8.0–8.3)
Mineral N (mg/kg, 0–50 cm)	58 (48–75)
Colwell P (mg/kg)	89 (63–105)
Colwell K (mg/kg)	757 (610–1050)
Exchangeable cations (me/100 g)	
Potassium	2.6 (2.1–3.4)
Calcium	41.8 (39.4–44.6)
Magnesium	7.8 (6.5–8.9)
Sodium	1.8 (1.5–2.1)
Conductivity (dS/m)	0.23 (0.17–0.37)

[1]Results presented in parentheses represent the range of values from individual plots at the Glenroy site. Soil bulk density was 1.1 g/cm^3.

6.3 ANOVA analyses

What was the effect of P and K fertiliser rate on yield, tuber number and tuber mass?

Fresh crop yields at the Glenroy site averaged 64 t/ha (the range across individual plots was 50–81 t/ha), which represented a typical outcome for the geographic area and season (Table 5).

There was no effect of P fertiliser rate on fresh (P = 0.695) or DM yields (P = 0.541), which reflected the high background soil P levels at the site (> 63 mg/kg Colwell P). There was no evidence that very high P fertiliser rates suppressed yields.

There was, however, a significant effect of K fertiliser rate on DM yield (P = 0.001) and, to a lesser extent, on fresh yields (P = 0.077). This was despite very high initial soil K levels at the site (> 2.1 me/100 g exchangeable K). In each case fresh and DM yields were maximised at the K0.5 and K1 fertiliser rates. The lowest yield was observed at the K2 fertiliser rate, although this was not significantly different to the K0 fertiliser rate.

It was not clear whether the increase in yield was related to more tubers or heavier tubers, or a combination of both (treatment differences in tuber number and tuber mass were not significant as both yield components were quite variable). In the case of mean tuber mass this variability likely reflected the visual sorting method used to size potatoes. Overall, there were strong correlations between fresh tuber yield and tuber number (r = 0.79, P < 0.001) and to a lesser extent mean tuber fresh mass (r = 0.35, P = 0.02). The DM content of the crop was not analysed statistically, but varied over a comparatively small range (19.6–21.3% DM).

It is important to note that in several instances there was a significant interaction between P and K fertiliser treatments. This suggested that crop yield responses to K fertiliser rate varied depending on P fertiliser rate. However, on closer inspection this appeared to be misleading as the interaction was influenced by unexplained variation in K responses at the P1 rate (Figure 1); for example, applying the K0 or K1 rate resulted in higher yields, whereas applying the K0.5 or K2 rate suppressed yields. We are aware of no obvious physiological basis for these differences. Plants counts were not recorded at harvest so it was not possible to determine if plot to plot differences in population contributed to this variation.

What was the effect of P and K fertiliser rate on yield distribution by size category?

The bulk of the crop yield fell within the target size range of 100–340 g/tuber (approximately 72% of total fresh yields, Table 6). Only a small proportion was sized either below 100 g (11%) or above 340 g (17%). In general, there was no significant effect of P or K rate on these size distributions. The exception to this was for the component of yield sized > 340 g/tuber, for which there was a significant response to P fertiliser rate. In this case, P0.5 resulted in a greater percent of yield in this tuber size range than either the P0 or P2 rate, with intermediate levels for the P1 rate. It appears likely that this reflected plot to plot variation in the grading of tubers by hand rather than a true response to P rate (P is more commonly thought to influence tuber number if limiting rather than size). In all cases there was no significant interaction between the P and K fertiliser rates.

Table 5. Effect of P x K fertiliser application on crop yields (fresh and dry), dry matter content, tuber number and mean tuber mass at the Glenroy trial site, 2010–11.

Fertiliser practice	*Fresh yield (t FW/ha)*	*Dry matter content (%DM)*[1]	*Dry matter yield (t DW/ha)*	*Tuber number (000/ha)*	*Mean tuber mass (g FW/tuber)*
P rate					
0	63.4	20.8	13.2	365	173
50	65.4	20.3	13.3	355	186
100	63.3	20.5	13.0	350	181
200	62.9	20.3	12.7	350	180
K rate					
0	61.3	20.9	12.7	343	179
150	66.2	21.3	14.1	362	183
300	65.7	20.3	13.4	358	184
600	61.8	19.6	12.1	357	173
P values[2]					
P rate	0.695 (4.6)		0.541 (1.0)	0.733 (32)	0.176 (11)
K rate	0.077 (4.6)		0.001 (1.0)	0.650 (32)	0.188 (11)
P x K inter.	<0.001 (9.3)		<0.001 (1.9)	0.093 (63)	0.944 (22)

[1]A composite sample from all replicates of each treatment was analysed for DM content. [2]*P* values less than 0.05 = strongly significant, *P* values between 0.05 and 0.10 = weakly significant, *P* values above 0.10 = not significant. Least significant difference (LSD) values are provided in parentheses and represent the smallest difference necessary between two means for a statistically significant test result (α = 0.05).

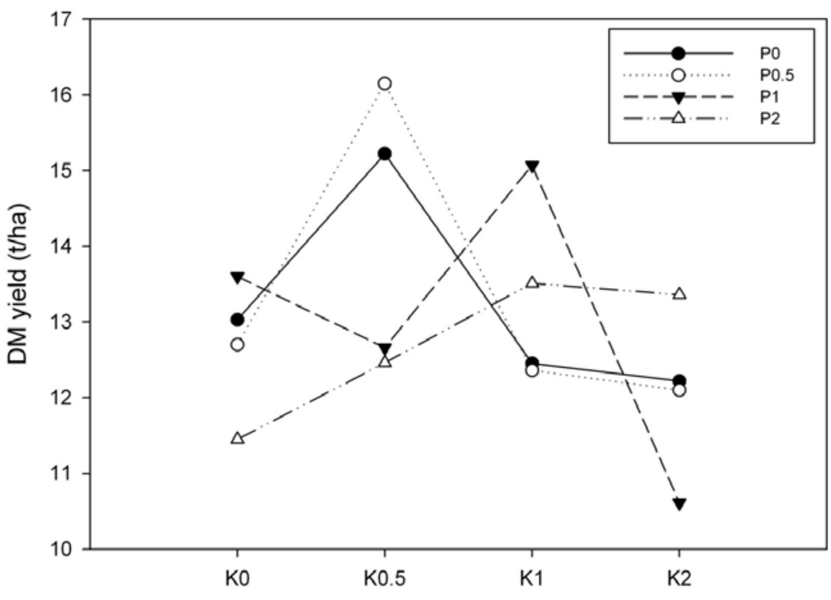

Figure 1. Effect of K fertiliser rate (K0, K0.5, K1 and K2) on crop DM yield at different P fertiliser rates (P0, P0.5, P1 and P2).

Table 6. Effect of P x K fertiliser application on fresh yield distribution by tuber size category at the Glenroy trial site, 2010–11.

Fertiliser practice	***Yield distribution by tuber size category (%)***				
	0–75 g	***75–100 g***	***100–170 g***	***170–340 g***	***340 g***
P rate					
0	4	8	32	43	13
50	3	7	29	40	21
100	4	8	28	42	18
200	4	7	29	45	15
K rate					
0	4	7	29	44	16
150	4	7	29	42	18
300	3	7	29	44	17
600	4	9	30	41	16
P values[1]					
P rate	0.947 (1)	0.495 (2)	0.336 (4)	0.116 (5)	0.008 (5)
K rate	0.105 (1)	0.141 (2)	0.843 (4)	0.510 (5)	0.791 (5)
P x K inter.	0.407 (2)	0.735 (4)	0.787 (8)	0.130 (9)	0.710 (9)

[1]*P* values less than 0.05 = strongly significant, *P* values between 0.05 and 0.10 = weakly significant, *P* values above 0.10 = not significant. Least significant difference (LSD) values are provided in parentheses and represent the smallest difference necessary between two means for a statistically significant test result (α = 0.05).

6.4 PARJIB analyses

Model fitting

Observed yields ranged from 6.5 to 16.1 t DM/ha across the four sites, with a mean of 12.5 t DM/ha. The model accounted for 79% of this observed variation in tuber DM yield, an increase in accuracy from the original calibration of approximately 4%. The average residual (observed yield minus simulated yield) was 0.1 (se 0.13) t DM/ha, which was not significantly different from zero. This indicates that there was no significant systematic bias in the simulations generated by the model. The RMS error resulting from the fitting process was 0.918 t DM/ha or 7.2%, also an improvement on the original calibration. A plot of observed yield against simulated yield provided a very good straight line relationship with a slope not significantly different from 1 and with no significant intercept (Figure 2).

These combined observations indicate that the model accounted well for variation in yield across all sites, and that the additional data from the most recent trial helped refine the fitting process.

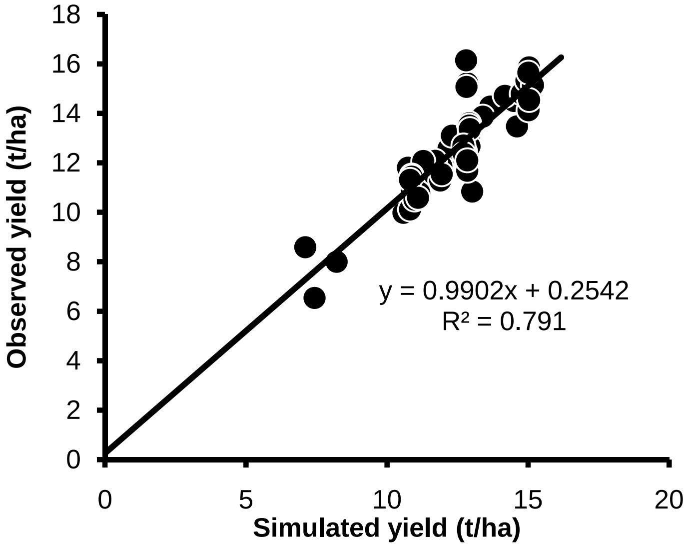

Figure 2. PARJIB model performance, observed versus simulated dry matter yield of tubers at all sites (2007–08: Penola West, Mingbool, Kalangadoo; 2010–11: Glenroy).

Responses to P fertilisers

In the data subsequently used to make forecasts with the fitted model, we selected Y_{max} values of 50 and 75 t FW/ha (representing average to above average yield outcomes from the trials), while Colwell P ranged from 10 to 100 mg P/kg soil with an average of 59 mg P/kg soil. Data collected in the most recent trial added strength to the upper end of the model calibration for P responses (the site average at Glenroy was 89 mg P/kg, whereas previously at Penola West, Mingbool and Kalangadoo it averaged 46 mg P/kg).

As with the previous trials, the model again indicated very little response to P fertiliser. At the low end of the soil test P range (5 mg P/kg) there would be some positive yield responses to a low rate of P fertiliser (Figure 3). The size of these responses would be greatest for well managed crops (i.e. crops that had a high Y_{max} after taking into account irrigation and N fertiliser management). As soil test P levels approached 25 mg P/kg (still considered comparatively low by industry standards) there was no clear benefit to P fertiliser application irrespective of Y_{max}.

It was noteworthy that with the inclusion of new data from the Glenroy site (high background P levels) there was no evidence to suggest that yield decreased if too much P fertiliser was applied. This also supported the findings from the ANOVA analysis.

In summary then, within the range of P fertiliser rates usually adopted by SA growers (75–150 kg P/ha), the forecast benefits of P fertiliser remain small unless soil Colwell P values are very low. This is supported by calculations of how much P is removed from the soil in harvested potatoes (a crop yielding 50 t FW/ha only removes approximately 25 kg P in the tubers). The forecast amounts of P fertiliser required to achieve various Y_{max} outcomes are summarised for a range of soil test P values in Table 1.

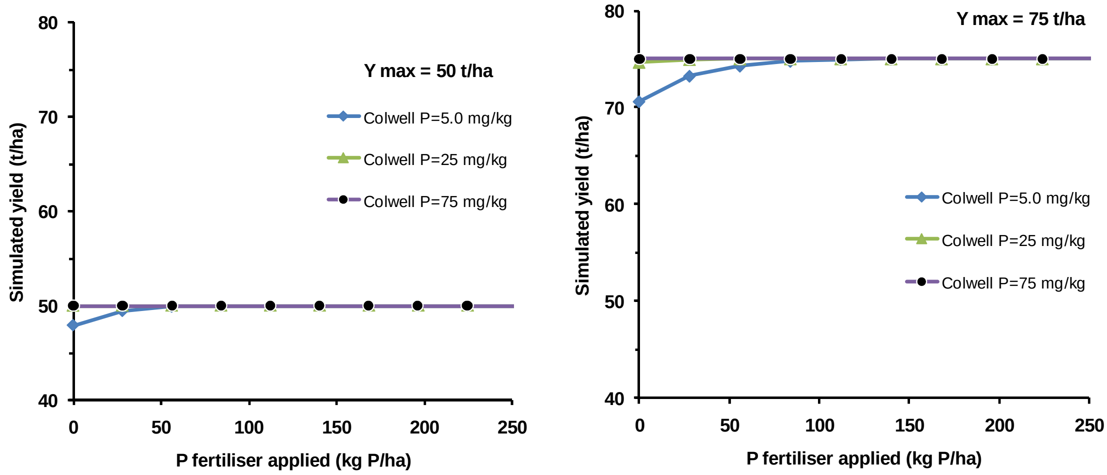

Figure 3. Simulated fresh yield response to broadcast P fertiliser at a range of initial soil test P values. The calculations are for crops where N, K and water are not limiting.

Responses to K fertilisers

Across the four sites, soil exchangeable K levels ranged from 0.12 to 2.78 meq/100 g with an average of 1.02 meq/100 g. As was the case with soil P levels, soil exchangeable K at the Glenroy trial site (2.63 meq/100 g) was much higher than in any of the previous trials (the average at Penola West, Mingbool and Kalangadoo was only 0.30 meq/100 g).

The model indicated that there would be strong yield responses to K fertiliser at soil K levels <0.30 meq/100 g, especially at a high Y_{max} (Figure 4). Even as soil K levels increase further (0.48 meq/100 g) there is still a positive response to K fertiliser at the high Y_{max}. In most cases, the model generally indicates a gentle rise in yield as K fertiliser rate increases beyond about 350 kg K/ha. The forecast amounts of K required to achieve high yield potentials can be very large, but may not be economically justified.

It is important to note that there was no predicted response to K fertiliser at the very high soil K levels observed at the Glenroy site (irrespective of Y_{max} potential). In many respects, this was consistent with the ANOVA analysis; while a significant K response was recorded at this site, there was no difference in crop yield between the 0 kg K/ha rate (K0) and the 600 kg K/ha rate (K2). The effects of K0.5 and K1 treatments were variable depending on P rate. Potential Na-K interactions were explored given the high Na content in the irrigation water at several sites (Na has the potential to replace K on exchange sites). However, there was no evidence of any meaningful interaction, or any negative effect of Na on yield outcomes.

In summary then, within the range of K fertiliser rates usually adopted by SA growers (200–300 kg P/ha), the forecast benefits of K fertiliser remain high, unless soil exchangeable K values are already very high or Y_{max} is very low. The forecast amounts of K fertiliser required to achieve various Y_{max} outcomes are summarised for a range of soil test K values in Table 2.

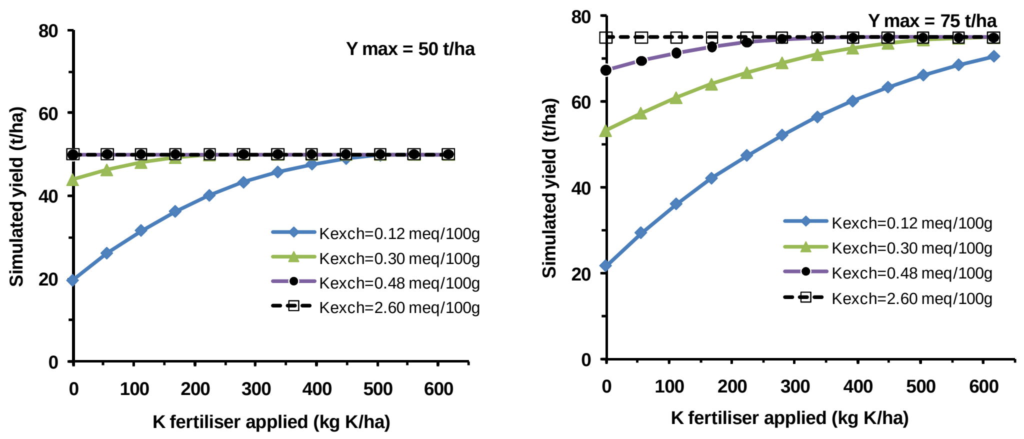

Figure 4. Simulated yield response to broadcast K fertiliser at a range of initial soil test K values. The calculations are for crops where N, P and water are not limiting.

7 Conclusions

The ANOVA analysis indicated that there was no effect of P fertiliser on tuber yields at the Glenroy trial site. This probably reflected the high soil test P level prior to the application of any additional P fertiliser. While there was a significant yield response to K fertiliser at this site, there was no difference between the effects of the lowest and highest K rates.

There was no effect of P or K fertiliser on tuber number or tuber mass, nor was there a clear impact of either nutrient on the distribution of yield in each of the tuber size ranges. This was consistent with the comparatively small effects of fertiliser treatments at the Glenroy site.

PARJIB model yield predictions matched well the combined dataset from the previous and new experiments. The RMS error of calibration was 0.981 t DM/ha, an improvement on the previous trials. The model accounted for 79% of the observed variation in tuber DM yield.

PARJIB predicted no yield response to P fertiliser unless soil P levels were low. This was in close agreement with the ANOVA analysis. When Colwell P values in the soil are low (< 10 mg P/kg) the model forecasts that there would be positive yield responses to modest P fertiliser applications for well managed crops. There was no evidence to suggest that yield may decrease if too much P fertiliser was applied.

PARJIB predicted clear yield benefits from K fertiliser within the range of soil exchangeable K found in the previous experiments (0.12–0.48 meq/100 g), but no clear response in the new trial (2.63 meq/100 g). The model generally indicates quite gentle rises in yield as the K fertiliser rate increases beyond about 350 kg K/ha, and the amounts of K that PARJIB predicts will be required to achieve maximum yield potentials can be very large. Larger applications may not be economically justified even if forecast yield is predicted to rise.

A series of recommendations in the form of look-up tables were developed from the model to help growers determine optimal P and K fertiliser applications rates that reconcile initial soil nutrient supply and the target yield potential in a given field.

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Potato Calculator™ yield calculations: Robert Zyskowski and Hamish Brown (Plant & Food Research).

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Appendices

Appendix I Nutrient content of irrigation water at the site, based on average values measured at the start and middle of the 2010-11 season from a pivot in an adjoining paddock

	NH_4-N (mg/L)	***NO_3-N (mg/L)***	***S (mg/L)***	***P (mg/L)***	***K (mg/L)***	***Na (mg/L)***	***Ca (mg/L)***	***Mg (mg/L)***
Irrigation water[1]	< 0.1	10.2	11.8	0.11	4.1	130	104	25.7

	Cu (mg/L)	***Zn (mg/L)***	***Mn (mg/L)***	***Fe (mg/L)***	***B (mg/L)***	***Cl (mg/L)***	***pH***	***Cond. (dS/m)***
Irrigation water	< 0.05	< 0.05	0.10	< 0.05	0.06	259	7.5	1.4

[1]Samples were analysed by CSBP Ltd, Western Australia. A total of 833 mm of irrigation was applied during the season (1 mm of irrigation = 10,000 L/ha).

Appendix II P x K treatment combinations, Glenroy trial site 2010–11

P x K treatment combination[1]	***Fertiliser applied at 28 DAP (kg/ha)***	
	P	***K***[2]
P0 K0	0	0
P0 K0.5	0	150
P0 K1	0	300
P0 K2	0	600
P0.5 K0	50	0
P0.5 K0.5	50	150
P0.5 K1	50	300
P0.5 K2	50	600
P1 K0	100	0
P1 K0.5	100	150
P1 K1	100	300
P1 K2	100	600
P2 K0	200	0
P2 K0.5	200	150
P2 K1	200	300
P2 K2	200	600

[1]All treatments received a high (unlimiting) N fertiliser rate of 310 kg N/ha; this was split-applied as 100 kg N/ha at 29 DAP and 210 kg/ha throughout the season as fertigation. All P was applied as single super (8.8% P). All K was applied as sulphate of potash (41% K).
[2]The K2 treatment was split-applied (50 : 50) at 28 DAP and 59 DAP to avoid any potential burning effect on the crop.

Appendix III Seasonal weather observations (minimum and maximum air temperature, rainfall and solar radiation) recorded at the closest weather station (6 km from the Glenroy trial site), 2010–11