Assessing break crop options for enhanced soil phosphorus availability

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Abstract
Any reduction in the need for fertiliser application through strategies that mobilise P from the 'soil P bank', enabling uptake by crops will provide a substantial economic benefit for the grower. Whilst many controlled environment studies report that certain break crop species have the capacity to mobilise P from less labile pools, there is scarce information suggesting mobilisation occurs in the field. This paper reports measurements of available P (Colwell and DGT) for root zone soils under break crops and wheat from five field locations in southern Australia, covering a range of climates and soil types differing in P sorption capacity. The aim was to identify potential for P mobilisation by break crops. Results demonstrate the enormous variability in plant-available P in the root-zone of different break crops across sites, as well as a clear influence of soil type on this soil P pool. More differences were detected between crops for DGT P than Colwell P. Across all sites, available P in the root zone soil of peas was consistently greater than other break crops, but not cereals. At one site, there was more available P in the root zone soil under lupins than the other break crops. However, it is concluded that the P mobilisation potential for any break crop cannot be assessed solely from available P measures in the root zone and a P budget for each crop is required.

Key Words
Break crops, grain legumes, P availability, root zone, P mobilisation

Introduction
To sustain crop production in Australia substantial amounts of phosphorus (P) fertilisers are applied to soils annually. Only 10–30% of applied P fertiliser is recovered by crops in the year following application due to applied P being fixed or precipitated into poorly available forms. This has resulted in a large 'soil P bank' in many agricultural soil which is estimated to be equivalent to $5-10 billion worth of fertiliser.

Soils in southern Australia are generally characterised by low P concentrations, leading to widespread P deficiency in crops. Phosphorus deficiency can be readily corrected by fertiliser application although current known sources of P for fertilisers are finite and are predicted to deplete rapidly over the next 50 years, potentially increasing input costs. Identifying suitable crops that can mobilise the 'soil P bank' is one approach towards the design of more efficient and economic P management for sustainable cropping systems. It is known from controlled environment studies that certain break crop species solubilise P in the rhizosphere (Hinsinger 2001; Richardson, Hadobas *et al.* 2001; Tarafdar and Claassen 1988). Phosphorus that is mobilised in excess of their own requirements may remain in the labile soil pools (as microbial or exchangeable P) and be more readily available to the following cereal crop, reducing P fertiliser requirements. Break crops are widely employed in rotation with cereals to reduce disease risk and, in the case of legumes, increase N inputs from fixation. The agronomic benefits of break crops for P have been far less widely reported, especially in Australia, although there are some reports that P efficient cultivars in rotations increase yield and P uptake of the following cereal crop (Nuruzzaman, Lambers *et al.* 2005). The aim of this research was to monitor P availability in the root zone of break crops during the growing season in order to identify those that may be increasing the availability of P.

Materials and Methods
Five field trial sites across southern Australia were selected to encompass differences in soil type, topography, climate, soil P sorption capacity as well as ensuring a range of different break crops (Table 1).
Plants were sampled twice during the season; at around flowering (designated peak vegetative growth) and at maturity (harvest). Soils were sampled pre-sowing and then post sowing root zone samples were taken at peak vegetative biomass and maturity. Root zone soil samples were defined as a soil sample (0-10cm depth) collected close to or over the plant. All samples were air-dried and ground to pass though a 2mm sieve prior to analysis. Plant-available P was assessed using: a) the extraction of P from soil using 0.5 M sodium

bicarbonate (Colwell 1963) followed by colorimetric determination of P-concentration in the extractant (Murphy and Riley 1962), and b) the Diffusive Gradient in Thin film (DGT) technique which uses a defined sink to determine flux of available P from a soil as described in Mason et al. (2010).

Table 1: Selected crop information and soil characteristics for the field trial sites.

Location	Break Crops 2011	$pH_{(H20)}$	PBI	DGT-P Sowing 2011 (µg/L)	Colwell P Sowing 2011 (mg/kg)	GSR 2011 (mm)	P fertiliser (kg/ha)	Yield (t/ha)	Dry matter (stubble) (t/ha)
Karoonda, SA - 4 soil types	Lupins	6.72-7.77	14-81	63-276	23-33	202	10	1.9/1.9/1.8/0.89[a]	5.7/8.5/8.6/6.4[a]
	Peas							0.23/0.68/0.59/0.94	4.1/5.9/6.7/6.3
	Canola							0.62/0.91/0.97/0.94	3.8/6.0/6.4/5.8
	Rye							1.3/1.8/2.6/1.9	8.5/9.1/9.7/9.3
Naracoorte, SA	Broad Beans	7.28	56	85	49	308	0/18/24[b]	2.7	6.7
	Peas							3.1	7.7
	Canola							2.3	12.2
	Wheat							4.0	14.1
Hopetoun, Vic - 2 soil types	Vetch	7.3-7.9	65-68	58[c]	16[c]	60	0	-	12.2/5.5[d]
	Fallow							-	-
	Peas							2.2/2.2[d]	4.0/5.4
	Canola							2.3/0.45	8.0/8.0
	Wheat							5.7/2.7	10.8/7.8
Longerenong (SCRIM, Vic	Vetch	7.52	142	126	65	232	20 or 23[e]	-	6.4
	Fallow							-	-
	Peas							4.3	7.2
	Canola							1.9	5.9
	Wheat							3.3	8.3
Junee, NSW	Lupin	6.38	54	205	99	230	5	-	8.4
	Peas							-	6.3
	Lentils							2.9	5.8
	Canola							3.1	10.6
	Wheat							4.4	11.1

Footnote: The four soil types at Karoonda were along a dune-swale transect grading from shallow sand to heavier flat. The two contrasting soil types at Hopetoun were a sand and clay loam. GSR: Growing Season Rainfall. PBI: Phosphorus Buffering Index. [a]Yield and DM values for Karoonda are for the sandhill/midslope(top)/midslope (bottom)/heavier flat [b]Beans received no P fertiliser, canola and wheat 18 kg P/ha and Peas received 24 kg P/ha. [c]Data not currently available for Hopetoun clay loam site. [d]Yield and DM are for sand/clay loam [e]Wheat and canola received 20 kg P/ha, peas and vetch received 23kg P/ha.

Results and Discussion

Plant Dry Matter & Grain Yield

Generally those sites with greater GSR, (i.e Naracoorte, Junee and Longerenong) had higher dry matter production and grain yield (Table 1) compared to Karoonda where the GSR was lower. Surprisingly, at Hopetoun which had an extremely low GSR, wheat yield on the sand was higher than all other sites, canola yield was similar to that at Longerenong and Junee, and peas yielded more than double those at Karoonda (Table 1). It is highly likely that stored soil moisture also influenced crop growth and final yield at these sites.

Colwell and DGT measures of P availability

There was no consistent relationship between the measured flux of P (DGT) and the P extracted using bicarbonate (Colwell P) for soils sampled at maturity across all sites (Fig.1). There were positive linear correlations for some of the heavier soils (Junee, Hopetoun clay, Naracoorte, Longerenong) but the different slopes preclude any generalised relationship. Further, there was a poor correlation on the sandy soils at Hopetoun and Karoonda, and a negative correlation on the Karoonda heavy flat. It has been demonstrated that the flux of P measured using DGT-P is highly correlated to plant P uptake (Menzies, Kusomo *et al.* 2005) and a more robust predictor of crop P uptake than P measured via extraction techniques (Mason, McNeill *et al.* 2010). Thus, it is likely that DGT may be a more sensitive technique for detecting the effects of break crops on changes in plant-available P in root zone soils.

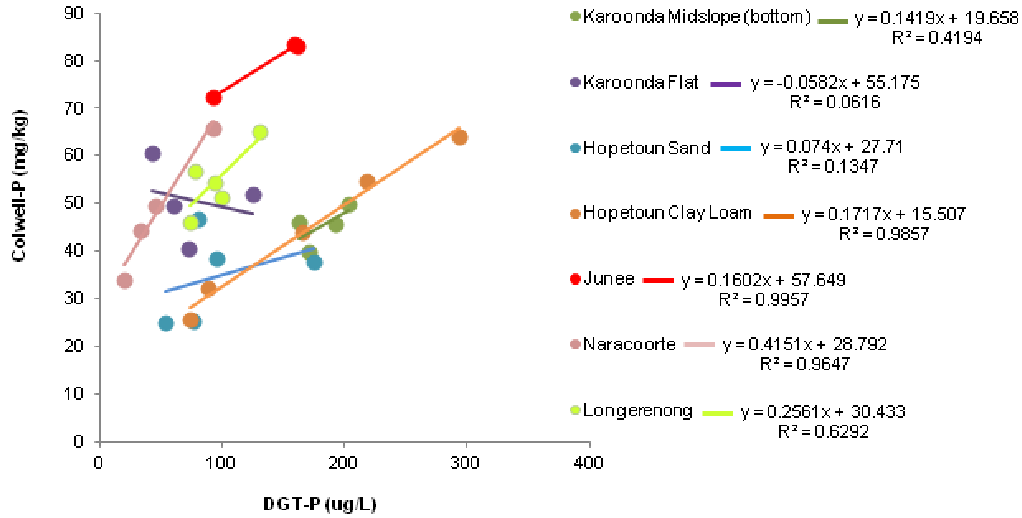

Figure 1: Relationships between measured Colwell-P and DGT-P for each break crop at harvest 2011.

P availability under the break crops

At all sites and sampling times except for grain maturity at Hopetoun (Fig 2) there were no significant differences in Colwell P in root zone soils from under different break crops. However, there were differences in DGT-P under the different break crops at harvest at Karoonda and Naracoorte (Fig 3). There were also differences at Hopetoun at maturity (Fig 2) and at peak biomass where DGT P was significantly greater under vetch and peas (261-305 µg/L) than under wheat and fallow (70-90 µg/L). However, it is acknowledged that any difference in available P in the root zone of crops cannot be definitively interpreted as P mobilisation since P uptake by the crop needs to be taken into account. These measurements of P concentration in shoots are currently underway. Also P input from fertiliser needs to be considered since many of these sites were fertilised (Table 1).

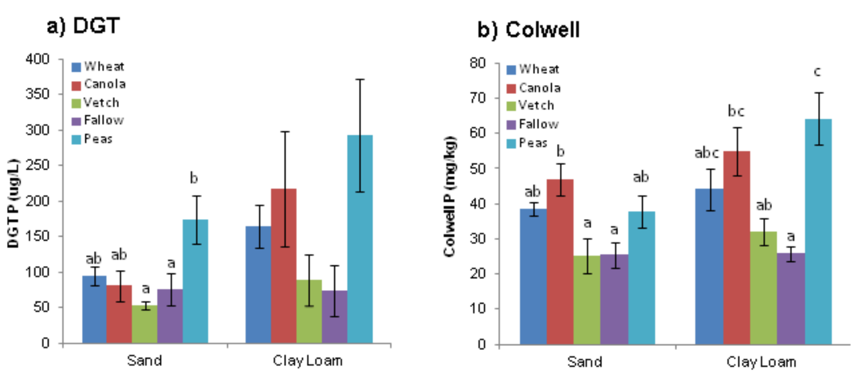

Figure 2: Available P measurements (a) DGT and (b) Colwell at harvest for root zone soils under different break crops, wheat and fallow at Hopetoun in Victoria

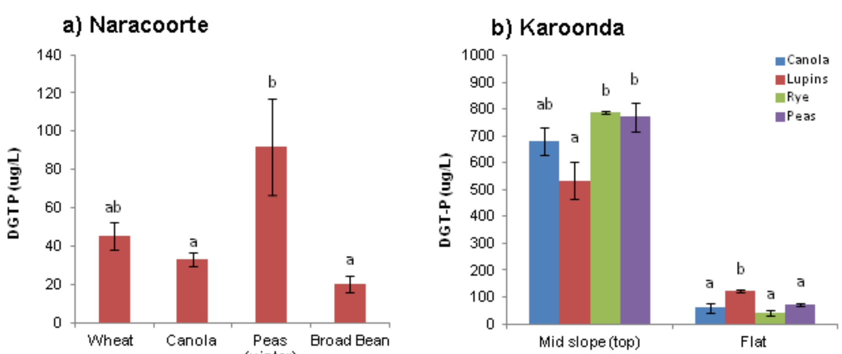

Figure 3: DGT P for root zone soils of different crops sampled at grain maturity from (a) Naracoorte and (b) Karoonda in SA.

At the lower rainfall sites of Karoonda and Hopetoun plant available P in the root zone generally increased between peak biomass and harvest, the exception being vetch at Hopetoun. It was most noticeable for the sandy soil at Karoonda (data not shown) where DGT-P increased by more than 400µg/L. The two ways in which break crops are likely to contribute to P availability in root-zone soil are (a) directly, via the action of root systems mobilising soil P and (b) indirectly via input of high P content labile residues (roots and shoots). This apparent mobilisation of P at the low rainfall sites following peak vegetative growth may reflect soluble P input from senescent shoot and root material during the drier period of the growing season.

There were no detectable differences in root zone available P measured by either DGT or Colwell under the different crops at Longerenong or Junee, at either peak biomass or grain maturity (data not shown). Due to the high P fertility at these sites, as indicated by the initial DGT-P and Colwell-P and relatively high PBI values (Table 1), break crops may be less induced to mobilise P or minor P mobilisation effects may not be detectable against a high available P background. However, there were some trends in break crop effects on available P at these two sites that were consistent with the other sites. In particular, across all sites available P in the root zone soil of peas was consistently greater than other break crops but not cereals (Figs 2, 3). At Karoonda on the heavier soil in the flat, there was more available P in the root zone soil under lupins than the other break crops (Fig 3).

Conclusion

Using DGT P as an indicator it was possible to detect differences in plant-available P in the root-zone under break crops across more soil types and sites than using Colwell P. However, there were no consistent significant effects of any one break crop, although there was a trend for available P in the root zone soil to be greater under pea and lupin crops. Clearly, the P mobilisation potential for any break crop cannot be fully assessed solely from available P measures in the root zone and a more complete P budget for each crop is being constructed.

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