Selecting a wheat or barley variety for phosphorus response or yield potential — which one is the winner?

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Abstract
Recent research efforts have assessed root traits that may improve phosphorus use efficiency (PUE) of cereal plants through improved phosphorus (P) acquisition. Replicated field trials assessing the response of four different wheat and barley varieties to P applications performed during 2015 and 2016 suggests that economic benefits of selecting a variety potentially requiring less P inputs is outweighed by the variety with greatest yield potential at current grain and fertiliser prices.

Keywords
phosphorus deficiency, climate, gross margins.

Introduction
Phosphorus (P) deficiency still occurs in selected regions across Southern Australia with major yield limitations occurring due to inadequate applications of P (Mason et al. 2010). Low soil P test values are commonly associated with soils that have moderate to high P buffering indices (> PBI 100) implying that replacement P programs based on general rules of thumb may not be sufficient to account for low fertiliser recoveries, thereby generating inadequate P replacement rates. In some cases application rates > 40 kg P/ha might be required to maximise yields, a fertiliser rate that under some circumstances may be greater than the economic optimum rate. Soil types prone to P deficiency are those of which contain considerable amounts of calcium carbonate or iron and aluminium with the former the predominant soil in southern Australia.

Wheat and barley varieties may vary in their responsiveness to P either by having root traits that increase access to soil P or by more efficient use of the P that is taken up. In combination with different yield potentials, external P requirements and P use efficiency (PUE) could vary. Identifying varieties that have greater PUE is of interest to many farmers in southern Australia due to the relatively low P levels driven by moderate to high P fixing soils in several regions. This paper summarises two years of P response trials in three different locations of each year.

Methods
Replicated field trials
Replicated trials were conducted at three locations in 2015 (Cummins, Pinery and Sherwood) and 2016 (Condowie, Cummins and Urania) in South Australia (Figure 1). Six rates of P as MAP (0, 5, 10, 20, 30, 50 kg P/ha) were sown with the seed. The nitrogen (N) applied with MAP was balanced in each treatment with urea so all treatments had equal amount of N at sowing. The P responses of four different wheat ('Cobra', 'Corack', 'Mace' and 'Trojan') and barley ('Commander', 'Compass', 'Fathom', 'LaTrobe') varieties were assessed. Each experiment was a split-plot design with variety as the main plot and P rate the subplot. The experiments were designed as a randomised complete block with four replicates. Weed management and in-season N applications followed commercial practice to achieve maximum yields. The trials were sown between 21 May and 2 June.

Assessments
Soil samples (0 – 10 cm, n = 16 for each trial) were taken within each control plot (0 kg P/ha, 0P) at sowing to assess the background soil P levels and variability across the field site. Soil P availability (Colwell P and DGT P) was measured along with the PBI. Trials were harvested at maturity and thousand grain weight was measured on a subsample of grain.

Figure 1. Locations of the six P response trials sown in 2015 and 2016.

For each variety, a Mitscherlich response curve (equation 1) was fitted between the grain yield (Y, t/ha) and P rate (kg P/ha):

$Y = Y_0 + a*(1-\exp(-b*x))$ …… (1)

where Y_0 = yield at 0P, a = yield increase with P application at the maximum attainable yield (Y_{max}), $Y_0 + a = Y_{max}$, b is the curvature coefficient of the response and x is the amount of applied P.

The P rate to obtain the maximum yield and the optimal P rate (P_{opt}), which was defined as the P rate that produced 90% of the grain yield response to P, was then derived.

The economic P rate (P*) was determined for each variety by finding the rate which provided the highest gross margin ($/ha). For each unit of P between zero and 50 kg P/ha, gross returns ($/ha) were calculated, by multiplying Y (equation 1) by the current wheat or barley price. The gross margin was then calculated by subtracting all variable costs, with applied P valued using current fertiliser (MAP) prices.

Overall response to P application (relative yield, RY) for each variety was calculated as:

$RY\ (\%) = Y_0 / Y_{max} * 100$ ……. (2)

Statistical analysis was performed using Genstat 15th edition (VSN International Limited, Oxford, UK) and significant differences tested at the 5% level.

Results

Soil test results for each site are presented in Table 1. Most sites were expected to be responsive to applications of P with the higher PBI sites generally having lower available P levels as measured by DGT. The Sherwood site was the exception as this site was not normally used for cropping and therefore previous P inputs had been low. The 2016 Cummins site had levels above critical values and therefore not expected to be responsive. While overall mean values suggested adequate P levels were present at Cummins in 2015, there was considerably variation in available P/PBI values within the trial site resulting in variable responses to P application.

There was only one site where there was a significant P and variety interaction which was at Cummins in 2016 (Table 2) which means that varieties did not differ significantly in their response to P. This may not be surprising given that modern varieties were selected under relatively high level of P nutrition.

Table 1. Summary of mean soil P characteristics at each of the 6 sites. Critical values for DGT is 56 (marginal = 48 – 67) for wheat and 68 (marginal = 50 – 94) for barley. Critical Colwell P was calculated based on relationships generated by Moody (2007).

Site	Year	Crop	PBI	Critical Colwell P (mg/kg)	Colwell P (mg/kg)	DGT P (µg/L)
Cummins	2015	Wheat	43	22	26	81
		Barley	59	22	25	71
Pinery	2015	Wheat	135	29	31	14
		Barley	135	29	28	17
Sherwood	2015	Wheat	39	22	11	16
		Barley	41	22	17	25
Condowie	2016	Wheat	146	29	29	26
		Barley	147	29	22	15
Urania	2016	Wheat	142	29	37	40
		Barley	118	22	36	59
Cummins	2016	Site average	54	22	37	77

There were contrasting growing seasons in 2015 and 2016; a year with a dry spring (2015) was followed by a favourable year (2016). In 2015, yields varied among locations with favourable growing conditions at Cummins resulting in yields reaching 7 t/ha. A warm, dry September/October at Pinery and Sherwood resulted in lower yields but still relatively high amounts of P were required to produce maximum yields (Table 2). There was no consistent difference in P_{opt} between wheat and barley. P* matched P_{opt} at Cummins but the relatively flat response curves (yield increase per unit of P applied) (Figure 2) at Pinery saw economical rates of approximately 30 kg P/ha compared to rates > 50 kg P/ha required to maximise yield.

Table 2. Summary of mean grain yield results from P response trials located at six sites across two years including the statistical output, the range of RY generated between varieties, and the variety and P rate which corresponded to the highest gross margin. W = Wheat, B = Barley, M = mean and V = variety.

Site	Year	Crop	P value (from ANOVA)			P response curve			RY (%)		Max. gross margin	
			P rate	V	P rate x V	Y_0 t/ha	Y_{max} t/ha	P_{opt} kg/ha	M	Range	V	P* kg/ha
Cummins	2015	W	<0.001	0.325	0.767	5.22	6.23	17	84	81 to 85	Corack	15
		B	<0.001	0.043	0.769	5.21	6.57	23	79	77 to 80	Compass	32
Pinery	2015	W	<0.001	<0.001	0.912	2.45	3.29	55	74	73 to 89	Corack	30
		B	<0.001	<0.001	0.846	2.74	3.69	46	74	64 to 76	LaTrobe	50
Sherwood	2015	W	<0.001	<0.001	0.997	0.2	0.84	21	24	5 to 32	Mace	26
		B	<0.001	<0.001	0.784	0.57	1.27	20	45	31 to 54	Fathom	12
Cummins	2016	W	0.019	0.738	0.045	5.63	5.87	0	96	85 to 103	*No response curves could be produced*	
		B	0.467	0.083	0.606	7.25	7.47	0	97	91 to 101		
Condowie	2016	W	<0.001	<0.001	0.575	4.89	5.96	50	82	78 to 83	Trojan	33
		B	<0.001	0.006	0.198	4.37	5.45	27	80	57 to 82	LaTrobe	22
Urania	2016	W	<0.001	0.014	0.844	8.04	8.69	33	93	89 to 95	Trojan	12
		B	<0.001	<0.001	0.801	6.81	7.26	22	94	91 to 98	Fathom	2

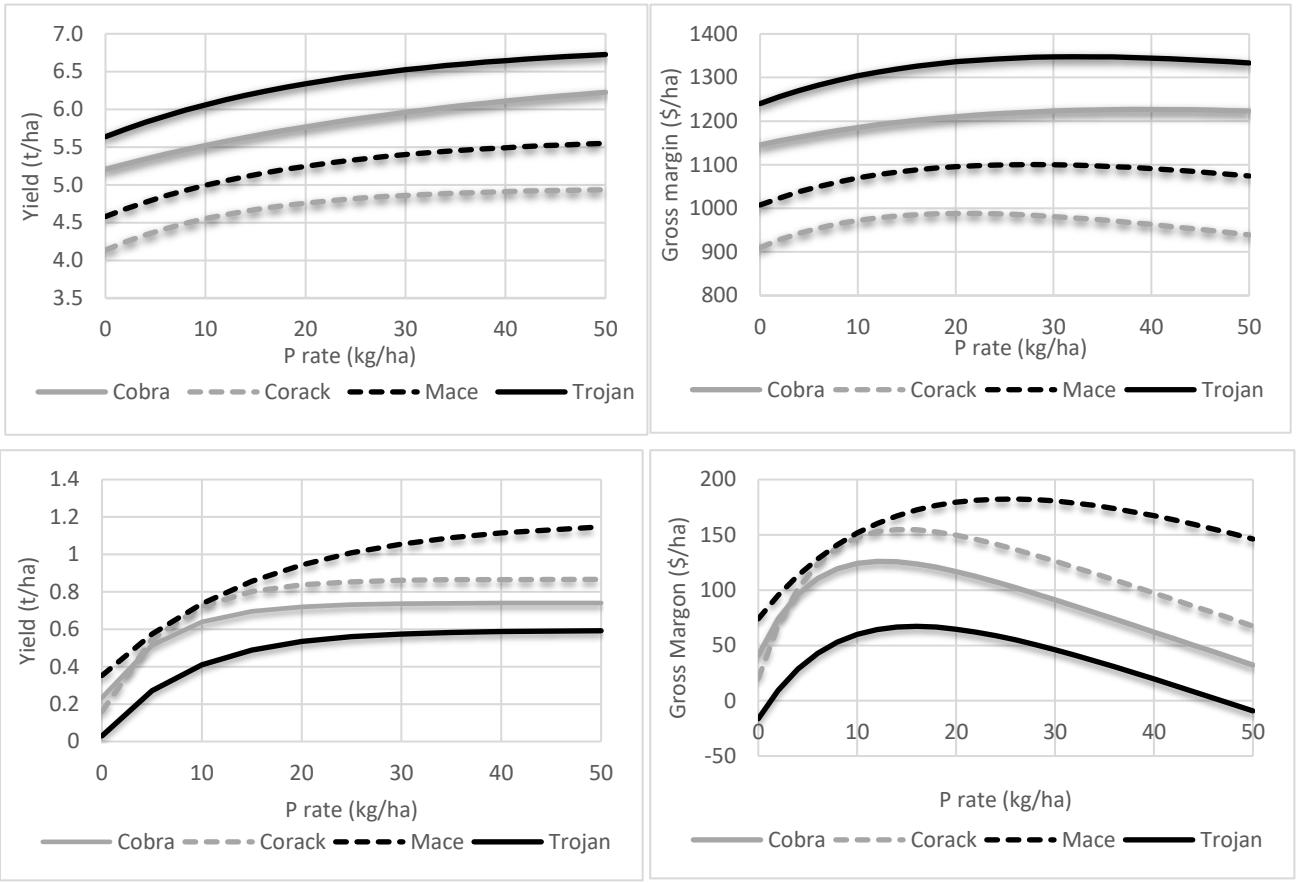

Figure 2. Yield response curves with increasing P rate for wheat varieties sown at Condowie (high PBI, upper) in 2016 and Sherwood (Low PBI, lower) in 2015 (left) and the resulting gross margin curves generated with P rate (right).

The 2016 growing season produced excellent yields at all sites with maximum yields of 5.5 – 6.0 t/ha at Condowie, 5.9 – 7.5 t/ha at Cummins and 6.8 – 8.0 t/ha at Urania. Compared to the 2015 season, the cool/wet finish favoured the longer season wheat variety 'Trojan' at Condowie and Urania. 'Latrobe' barley performed well at all three sites. As predicted by soil test results, the Cummins site was not responsive to P. The absence of a significant variety and P interaction at most sites meant the highest yielding variety provided the best profit.

Conclusion

At current fertiliser and grain prices the choice of which wheat or barley variety to sow in Southern Australia should be made on yield potentials, sowing windows and crop rotations first with the consideration of reducing fertiliser costs with a high RY variety a low priority.

References

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