Phosphorus Use In Wet and Dry Soil Conditions

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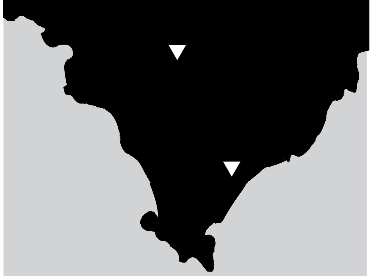
Searching for answers



Location:
Langhorne Creek, McAnaney Family, sand over calcrete
Karoonda, Loller Family, deep sand and sand over clay
Halidon, Schober Family, deep sand over clay
Wanbi, Obst Family, loamy sand over calcrete
Minnipa, MAC, alkaline sandy loam
Wharminda, Hunt Family, sand over clay
Plot size
10 cm diameter open bottom core planted within a 3 x 4 m area with 4 reps.

Key message

- **The amount of applied phosphorus (P) fertiliser that was used by the crop plant increased with increasing simulated rainfall.**
- **The amount of P fertiliser used was not directly related to whether the soil was deficient or sufficient in P, but the growth response was.**
- **The use of subsoil P increased with the addition of P fertiliser, suggesting that the P fertiliser stimulated root growth into the subsoil.**

Why do the trial?

Phosphorus fertiliser efficiency varies across sites and seasons. Soil fertility and seasonal soil moisture conditions both influence this fertiliser efficiency. The efficiency of fertiliser use by the target crop has rarely been quantified directly and is often assumed to be 15-25% (McLaughlin et al. 1988). In larger scale field trials fertiliser efficiency can be measured using indirect methods where a control of no P is compared with plus P treatments, but this measurement is susceptible to interference from other factors (disease, soil type change etc.) and lack of response does not mean that the fertiliser did not contribute P to the crop.

Seasonal conditions also influence the relationship between fertiliser and topsoil and subsoil P uptake by crops. Our hypothesis was that under dry conditions a plant might push more roots into the subsoil and access nutrients from deeper in the profile, due to the inaccessibility of nutrients in the dry topsoil. To test this we measured topsoil and subsoil contribution to plant P uptake in response to wet and dry conditions at 3 of the 7 sites (choosing sites that actually had subsoils to extract nutrients from!).

How was it done?

We had 7 experiments in the field under rain-out shelters where we directly measured the uptake of P fertiliser (using radioisotope) under wet (decile 7-8) and dry (decile 2-3) in-season conditions. Our 7 experiments were at Karoonda (2 soil types), Wanbi, Halidon, Langhorne Creek, Wharminda and Minnipa. These soil types ranged from neutral to alkaline pH and P deficient (Langhorne Creek and Wanbi) to sufficient (Karoonda, Halidon, Wharminda and Minnipa) soil test (CDGT-P) values (Table 1).

Table 1 Soil test results

Site	Langhorne Creek	Karoonda (Deep sand)	Karoonda (Sand/ clay)	Halidon	Wanbi	Minnipa	Wharminda
pH (H_2O) topsoil (0-10 cm)	7.5	6.6	6.5	6.9	8.8	8.6	6.8
pH (H_2O) subsoil (15-50 cm)	7.7 - rock	7.1 - 7.1	7.0 - 9.0	7.6 - 8.8	8.8 - rock	8.8 - 8.8	8.8 - rock
Carbonate (%)	<0.2	<0.2	<0.2	<0.2	6.1	1.6	<0.2
Colwell P* (mg/kg)	52	26	29	54	28	41	35
CDGT - P* (μg/L)	58	206	241	75	30	91	114

** Critical value for colwell P is 15 - 20 mg/kg for light textured soils while for CDGT - P it is 60 (µg/L)*

We added P fertiliser containing a radioactive tracer that gives the fertiliser a unique ‘fingerprint’ so that we can track the uptake of fertiliser into the plant. The P fertiliser was added at 15 kg P/ha as phosphoric acid. Liquid fertiliser was used because it is difficult to manufacture consistent and comparable radioactive fertiliser granules. There was a control of no P fertiliser for comparison and all treatments received 20 kg N/ha as urea and 2.5 kg Zn/ha as zinc sulphate at sowing. The Mallee sites received 50 kg N/ha at Zadoks growth stage 30 (late tillering).

The plants were sown into soil at 50% of field capacity (ideal sowing moisture). We then watered the plants to simulate decile 2-3 vs. decile 7-8 conditions to represent wet sowing-dry growth phase and wet sowing-wet growth phase scenarios. It was quite difficult at times to achieve the decile 2-3 growing conditions due to the prevalence of good subsoil moisture reserves in 2010.

Wheat (cv. Axe) plants were grown until Zadoks 47 (head in the boot) and harvested by hand so that we could measure dry weight, P content and fertiliser content using radioactivity. We recognise that there is a difference in P use efficiency in different cultivars of wheat. We selected the cultivar Axe because it has a short growing season and due to the decay of radioactivity limiting the length of experiment to 3 months, we wanted a variety that would be near completion of the P uptake phase of the growth cycle (root uptake of P tends to be limited from flowering onwards).

To measure the contribution of topsoil and subsoil residual P to plant nutrition at 3 of the sites (Karoonda deep sand, Halidon and Minnipa) we had to devise a more complicated methodology. In this experiment we labelled the fertiliser with one isotope and then used another isotope of P to fingerprint (label) the topsoil. We used a physical barrier to prevent roots growing into subsoils in some treatments and were therefore able to determine the use of subsoil P by difference. This experiment also used the simulated decile 2-3 and decile 7-8 rainfall applications.

What happened?

Plant Response to Phosphorus

At Wanbi, Langhorne Creek and Wharminda, the addition of P increased shoot dry weight, while at Wanbi decile 7-8 also increased shoot dry weight compared with decile 2-3 (Table 2). At the Karoonda sand over clay and Halidon there was a negative growth response to P addition (reason unknown) while at Minnipa site there was no response to P fertiliser addition. At all three sites there was no difference between the simulated low and high rainfall treatments (Table 2). We think this is because the roots were able to readily access subsoil moisture and so the topsoil watering treatments did not affect shoot growth. By contrast, on the Karoonda deep sand there was no response to added P but we did see increased shoot dry weight in the wet treatment.

Fertiliser Efficiency

‘Fertiliser efficiency’ is the percentage of the P fertiliser added that was used by the crop plant. The fertiliser efficiency was higher in the decile 7-8 treatment in all soils except the Karoonda sand over clay and the Wharminda soils (Table 3). The Wharminda result is surprising as this soil recorded a shoot response to both the extra rainfall of decile 7-8 and P addition. The fertiliser efficiency was in the order of 3-30% of P added. At P application rates of 10-20 kg P/ha this equates to 0.3-6 kg P/ha being used in the year the fertiliser is applied. This remaining (unused) fertiliser will also have residual value in subsequent seasons (depending on climate and soil conditions).

Topsoil vs. Subsoil P uptake

Although none of the three sites (Karoonda deep sand, Halidon and Minnipa) showed a dry weight response to the addition of P fertiliser, the P fertiliser still made a significant contribution to total plant P uptake in the order of 7-10% of total plant P at Minnipa and up to 43-44% of total plant P at Halidon (Table 4). The contribution of subsoil P to plant P nutrition was increased by adding P fertiliser (Table 4). The very low contribution of the subsoil to crop P uptake at Minnipa may be related to the high subsoil pH (pH 8.8 cv. pH 7.1-7.6 for Karoonda and Halidon, Table 1), which can both inhibit the availability of P and indicate the presence of other subsoil constraints such as boron and sodicity (which is currently being tested for).

Table 2 Plant dry weight t/ha in response to P fertiliser and applied rainfall

Site	Langhorne Creek		Karoonda (Deep sand)		Karoonda (Sand over clay)		Halidon		Wanbi		Minnipa		Wharminda	
	Decile		Decile		Decile		Decile		Decile		Decile		Decile	
	2 - 3	7 - 8	2 - 3	7 - 8	2 - 3	7 - 8	2 -3	7 - 8	2 - 3	7 - 8	2 - 3	7 - 8	2 - 3	7 - 8
0P	2.7	2.1	1.9	3.5	5.4	5.0	1.2	2.2	1.0	1.6	7.3	6.7	2.0	3.7
+P	3.4	4.5	2.4	3.7	4.2	4.2	1.0	0.9	1.9	3.5	7.1	6.8	3.2	4.6
LSD (P<0.05)	*Fert (1.1)*		*Water (0.4)*		*Fert (0.7)*		*Fert, water (0.7)*		*Fertxwater (0.5)*		*No effects*		*Fert (0.7)*	

Nutrition

Table 3 Fertiliser efficiency (%) under decile 2 - 3 vs. decile 7 - 8

Site	Langhorne Creek	Karoonda (deep sand)	Karoonda (sand/ clay)	Halidon	Wanbi	Minnipa	Wharminda
Decile 2 - 3 Fertiliser Efficiency	25.0	7.6	22.7	5.7	8.9	2.6	22.8
Decile 7 - 8 Fertiliser Efficiency	33.5	15.5	22.1	18.6	16.9	10.4	24.2

Statistics: Site x Water treatment (P<0.05, LSD 6.0)

Table 4 Plant phosphorus that came from fertiliser, topsoil and subsoil (%) for decile 2-3 vs. decile 7-8

Site	Karoonda (Deep Sand)		Halidon		Minnipa	
Watering	Decile 2 - 3	Decile 7 - 8	Decile 2 - 3	Decile 7 - 8	Decile 2 - 3	Decile 7 - 8
	Plus P fertiliser					
Fertiliser P (%)	15.1	18.5	44.2	43.4	6.8	10.2
Topsoil P (%)	29.0	27.5	29.0	50.0	89.4	71.3
Subsoil P (%)	48.0	53.2	19.0	7.0	6.7	18.3
	No P fertiliser					
Topsoil P (%)	75.5	79.5	97.2	84.8	95.0	86.4
Subsoil P (%)	24.5	20.6	3.7	15.2	5.0	13.6

Statistics: Site x Water x P Source (fertiliser/topsoil/subsoil) (P<0.05, LSD 11.9)

What does this mean?

The addition of P fertiliser to a P deficient soil will increase shoot biomass. The CDGT-P soil test was able to reliably predict which soils were P deficient. In general the amount of P fertiliser added that was used by the crop plant was greater for decile 7-8 compared with decile 2-3 simulated rainfall. The fertiliser efficiency ranged from 3-30% and was different for different soils, but a more P deficient soil did not necessarily have a higher P fertiliser efficiency. The importance of subsoil P to crop plant P uptake increased with the addition of P fertiliser, suggesting that the fertiliser P is important for root vigour enabling the crop plant to then access subsoil nutrients.

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