Crop response to deep placement of phosphorus in a Vertosol soil in the Northern Grains Region of NSW

Thomas Tendo Mukasa Mugerwa^{1*}, Ricky Graham¹ and Peter Formann¹.

¹New South Wales Department of Primary Industries, Tamworth NSW 2340

(*Corresponding author - tendo.mukasa.mugerwa@dpi.nsw.gov.au)

Abstract

The fertile soils of the Northern Grains Region supported cropping for many years before yields started to become limited due to nutrient availability. Phosphorus (P) is a key plant nutrient which has traditionally been applied as starter fertiliser, with the seed. However, due to the relative immobility of P, P rundown in subsoil (10-30 cm) readily occurs in soils in the Northern Grains Region. This is beneath both where starter fertiliser is placed and where plant matter is returned. Low levels of phosphorus in the subsoil can have significant impacts on crop yield, particularly during periods where the topsoil (0-10 cm) is dry. The aim of this experiment was to investigate whether or not placing P at depth would increase grain yields of crops growing in a Vertosol under limited rainfall. An experimental site with varying rates of deep-placed P was established at Gurley, New South Wales (NSW), in 2015. In 2017, a wheat crop was sown within these varying P treatments in the presence or absence of starter fertiliser. Where starter fertiliser was applied, a significant yield response was recorded where deep-placed P was applied at a rate of 80 kg P/ha. Results of this study demonstrated the potential impact on wheat yields of placing P deeper in the profile.Ultimately, the 4 rights (4Rs) of nutrient stewardship should be closely followed in order to increase the chances of getting a favourable return on nutrient application.

Key Words

Phosphorus, deep-placement, Vertosol, grain yield.

Introduction

Soils in the Northern Grains Region (taking in central and southern Queensland, through to Northern New South Wales), in particular the black/grey cracking clay soils (Vertosols) have historically been very fertile. However, with the adoption of no-till farming systems and the associated intensification of cropping, reserves of mineral nutrients such as phosphorus (P) have gradually been run down over several decades of cropping (Bell *et al.*, 2012). The region of nutrient rundown has typically been in the 10 to 30 cm layer, beneath both where starter P is placed and where residual plant matter is returned (Bell *et al.*, 2012). As a consequence, stratified distribution of P occurs within the soil profile, with P more readily available in the surface layers (0 to 10 cm) and less available further down the profile. Significantly, including in Vertosols, growing crops rely on subsoil moisture and nutrients for extended periods within in the growing season, especially when the topsoil is dry (Bell *et al.*, 2014). Unless immobile nutrients such as P are present in the subsoil, crop roots are unable to access nutrients required to meet seasonal yield potential. In dry seasons, when crops are reliant on stored water for growth, P is almost entirely obtained from the sub-surface layers (10 to 30 cm) for most of the growing season (Bell *et al.*, 2018).

Standard industry practice has been to apply starter P in or near the seeding trench at sowing. This practice was adequate when subsoil P reserves were sufficient to meet the larger P requirements for crop growth. However, with declining native subsoil P fertility, it is apparent that alternate fertilizer P application strategies are now required in order to meet total crop P requirements and yield potentials.

The aim of this experiment was to test the hypothesis that placing immobile nutrients such as P deeper in the soil profile would increase wheat grain yields above the traditional approach of starter P placement in or near the seedling row, close to the soil surface at seeding. A number of experimental sites have been established across the Northern Grains Region in order to test this hypothesis. The results discussed in this paper relate to the experimental trial site at Gurley, NSW.

Methods

The experiment was conducted at Gurley (NSW 2398) during the 2017 winter growing season (Sowing date: 16 May 2017, Harvest date: 25 October 2017). The trial site was characterised by a grey Vertsosol and had a chickpea (HatTrick) crop in 2016. Wheat (Spitfire) was sown at a target rate of 120 plants/m2 on 33 cm spacings, with each experimental plot being 12×3 metres (1 x w) in size. The experiment consisted of factorial combinations of six tillage/deep P treatments with or without the application of Starter fertiliser in the form of monoammonium phosphate (MAP, Granulock®Z), randomised using the DiGGer software (Coombes 2009). Starter fertiliser was placed within the seedling trench at sowing. Each treatment consisted of 6 replicates (Table 1). A 'Farmer Reference' (FR) treatment was included as an untreated control, to provided baseline data on yield and nutrient uptake when no additional nutrient input and soil disturbance occurred. The deep-P was applied as triple superphosphate (TSP, monocalcium phosphate) to a depth of ~ 20 cm, parallel to the sowing direction (75 cm row spacings). Farmer Reference treatments were balanced for N and S using urea and gypsum. All plots also received an additional 70 kg N/ha, side banded as urea (46% N) at sowing. Starting soil moisture at the trial site was 73 mm (0-120 cm, Plant Available Water). Starting soil N was approximately 107 kg/ha (0-120 cm), with starting soil Colwell P measured at 8 and 3 mg/kg at depths of 0-10 and 10-30 cm, respectively. At crop maturity, measurements of grain yield, grain protein/moisture/nutrient content, plant density, plant biomass and plant nutrient content were taken. Treatment means were compared by conducting two separate analysis of variance (ANOVA, Fisher's Least Significant Difference) assessments using Genstat for Windows, 19th Edition (Genstat 2018). The first analysis looked at the response to starter fertiliser (P) and the second analysis compared the 6 tillage/deep-P treatments.

Treatment	Applied	Starter	Cultivation
	Phosphorus,	Fertiliser	
	Triple		
	Superphosphate	•	
	(kg P/ha)		
1	0	Minus	Farmer Reference (no
			deep-P application)
1	0	Plus#	Farmer Reference
			(no deep-P application)
2	0	Minus	Deep-ripped*
2	0	Plus#	Deep-ripped*
3	10	Minus	Deep-ripped*
3	10	Plus#	Deep-ripped*
4	20	Minus	Deep-ripped*
4	20	Plus#	Deep-ripped*
5	40	Minus	Deep-ripped*
5	40	Plus#	Deep-ripped*
6	80	Minus	Deep-ripped*
6	80	Plus#	Deep-ripped*

Table 1. Phosphorus treatments applied to experimental pl	ots
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* Deep-ripped to a depth of 20 cm

60 kg/ha Granulock[®]Z

Results

In-crop rainfall at the trial site was 124 mm. Annual rainfall (2017) in the locality was 462.2 mm, compared to the long-term average of 669.49 mm.

A significant yield response was recorded where starter fertiliser was applied when the overall average yield from treatments with starter fertilizer was compared to the average yield from treatments without starter fertilizer. Across all treatments, starter fertiliser use delivered a 19% increase in yield, equivalent to an additional 500 kg/ha at Gurley in 2017 (Figure 1).



Figure 1. Grain yield response of wheat to starter P application averaged across treatments, with or without starter P. Bars with the same letter are not significantly different (P<0.05).

In the presence of starter fertiliser, a significant increase in yield was also recorded where deep-P was applied at rate of 80 kg P/ha,. At this rate of P application, a 17% yield increase (additional 500 kg/ha) was recorded relative to the FR treatment and a 36% yield increase (additional 900 kg/ha) relative to the deep-ripped treatment where no P was applied (Figure 2). A yield loss was recorded in the deep-ripped treatment where no P was applied relative to the FR treatment. There were no statistically significant interactions between starter P and deep-P application. Grain yields did not appear to be limited by nitrogen as grain protein concentrations of wheat samples all exceeded 14%, across treatments (data not shown).





Discussion

Results from the deep-P trial conducted at Gurley in 2017 demonstrated that significant yield benefits could be obtained from P application, with both starter fertiliser and deep-P providing significant yield increases. In relative terms, the size of the overall yield response recorded where starter fertiliser was applied (19% yield increase in comparison to treatments without starter P) was quite large, however, not unexpected. The site at Gurley had a Colwell P of 8 mg/kg (0-10 cm) and was therefore low in P. The site had Zinc (Zn) levels (DTPA) of 0.48 mg/kg and 0.31 mg/kg in the 0-10 and 10-30 cm layers respectively, so the Zn present in the starter P may have contributed to the increases recorded. However, Gurley also experienced early-season conditions that were favorable towards the exploitation of starter fertiliser in early crop growth. Relatively high levels of P-uptake in the absence of deep-P further indicated that there was a significant uptake of starter P, particularly early in the season, with a significant increase in biomass P recorded from the FR treatment where starter fertiliser was applied (data not shown).

Even though there was a trend of increases in yield with increasing rates of deep-P, a significant increase in yield (relative to the FR treatment) was only recorded where deep-P was applied at 80 kg P/ha (Figure 2). The generally poor response to residual TSP is consistent with the varied results that have been obtained at other trial sites in Northern NSW (Graham *et al.*, 2017a; Graham *et al.*, 2017b; Graham *et al.*, 2017c), where TSP was also applied at depth (data not shown).Similar observations have also been recorded in deep-P trials in southern Queensland field sites (Bell 2018). Further, glasshouse studies (Moody 2018) have indicated that P-uptake may be influenced by the form of P that is applied, with soil characteristics also influencing nutrient availability. The relatively inefficient use of deep-P (TSP) recorded in this study, especially relative to the very efficient use of the smaller amounts of P as MAP, added further weight to these observations.

Conclusion

In 2018, a fresh deep-P treatment was established at the Gurley trial-site where deep-P was applied as MAP. The fresh treatment was set up to re-establish a yield benchmark and will be compared to treatments with residual rates of TSP. Ultimately, increases in yield in response to deep-P application will depend on the ability of the crop to access and utilise this nutrient. Therefore, soil type, P placement, time of P application, P amount, P rate and moisture availability all play key roles in the potential crop response to deep-P. The results from Gurley and other trial sites in 2017 also confirmed the effectiveness of starter fertiliser use.

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