Opportunity to increase phosphorus efficiency through co-application of organic amendments with mono-ammonium phosphate (MAP)

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Keywords: Compost; Barley (*Hordeum vulgare*); partial substitution; fertiliser efficiency

Introduction

As the world's population continues to increase towards the predicted 2050 figure of 9 billion (Fischer et al., 2002) so too does the demand for food. Until the early 1950s, world agricultural production kept pace with population mainly through the expansion of cultivated area and increasing crop yields (i.e. production per unit area) (Gilland, 1993). This was achieved through breeding improvements, expanding and improving irrigation systems, and protecting crops from disease, insects, and competition from weeds, as well as applying increasing quantities of chemical fertilisers (Gilland, 1993). However, the sustainability of the required agricultural production is in question if the raw inputs of many fertilisers, such as those supplying phosphorus (P), are finite, and if fertiliser costs continue to increase such that production profitability is lost (Cordell et al., 2009). Therefore, alternative, or simply more efficient, sources of nutrition are required. The efficacy of single and combined applications of compost and synthetic fertiliser were compared in a glasshouse trial to determine the potential for reduction in synthetic fertiliser usage through partial substitution with compost. A microbial inoculant alone and in combination with compost or synthetic fertiliser was also included in the comparison undertaken. This project tests the hypothesis that conventional synthetic, and organic, fertilisers could be used together to maintain or increase yield, whilst reducing demands on conventional, mined, synthetic P supplies through greater fertiliser efficiency.

Materials and Methods

Barley (*Hordeum vulgare* L. cv. Hindmarsh) was grown in a glasshouse trial set up in 12.7 x 12.7 cm plastic pots using soil collected to a depth of 5 cm from a site at Charles Sturt University, Wagga Wagga, Australia (S 35° 3' 56.556" E 147° 19' 27.696"), as in Gale et al. (2011). Initial nutrient analysis is shown in Table 1. The trial consisted of 11 treatments comprising single additions or combinations of compost, mono-ammonium phosphate and a microbial inoculant (Table 2). Treatments were replicated four times. Fertiliser applications of 20 kg P/ha (equivalent to 91 kg MAP/ha) are generally accepted as the required P application rate for grain production on similar acidic soils (Schefe et al, 2008) and was used as the baseline application rate for P fertiliser. Compost and MAP were applied singularly and in combination with each other so that rates of 20 kg P/ha, measured as Colwell (1963) available P, were applied to each pot. Applying compost at a rate to give 20 kg P/ha resulted in a compost application equivalent to 33.4 t/ha.

Compost for this trial was produced in windrows similar to Kuhlman and Cormac-Walshe (2000) from material sourced by the Charles Sturt University green waste management program with feedstocks including wood shavings used in horse stables, grape marc, and food scraps from campus kitchens. The chemical constituents of this compost are also outlined in Table 1. The synthetic fertiliser used in the trial was commercial Mono-Ammonium Phosphate (MAP) that contained 21.9% available P, as measured by the Colwell P (1963) method. 'Microsoil', a patented liquid microbial fertiliser and inoculant said to enhance the efficacy of solid and liquid chemical fertilisers, was prepared for application and applied by following the manufacturer's instructions (Microsoil, 2011). Two applications of inoculum were made to pots at equivalent field rates, at sowing and after 4 weeks of the glasshouse trial, alone or with MAP or compost applied at rates equivalent to 10 kg P/ha.

After eight weeks growth both the above and below ground plant material was collected, weighed and analysed for P content as in Gale et al. (2011). The amount of P which was present in each pot at the beginning of the trial (Initial P) was determined based on the sum of the measured soil P prior to the experiment and the calculated additions (Table 2). The cumulative P which was taken up into the leaves and roots of the barley is also presented. All statistical analysis was conducted using GenStat Version 5. Analysis of variance (ANOVA) was used to calculate least significant differences (LSD) to determine significant differences between means.

Results and Discussion

Uptake of P was greatest when compost constituted more than half of the 20 kg P/ha (Table 2). Uptake efficiency (P Uptake / Initial P) was also greatest with 50% of the P applied as compost. Lower P uptake in the treatments containing greater than 50% MAP may be explained by more P-binding. P-binding occurs when available P forms complexes with Fe and Al under acidic conditions (Evans and Condon, 2009; Schefe, et al., 2008) created by nitrification around the MAP granule. The compost treatments had a pH around 7.6 ($CaCl_2$) and were therefore less likely to have had this type of binding occur. An alternative explanation is that some of the pool of total P in compost was mobilised to create a larger pool of available P as the trial continued. This may then have resulted in an increase in P taken up. A key implication of increased uptake efficiency, when more than 50% compost is applied, is that total application of organic and/or synthetic fertiliser required per crop will be less because the crop takes up a higher proportion of what is applied.

There were no significant differences in dry matter yield (DMY) between treatments meaning that the greater P uptake of the treatments with more than 50% compost resulted in significantly lower utilisation efficiency (DMY / P Uptake) for these treatments. Alternatively, significantly lower P uptake, without any significant difference in DMY, from the MAP only treatment resulted in the greatest utilisation efficiency. That is, for the same amount of DMY, less P was taken up into the plant. As with its effects on uptake efficiency, P-binding is likely to be part of the reason for this result. Given that P uptake was significantly higher with the addition of compost is it proposed that utilisation efficiency is significantly lower (Table 2) due to other nutritional limitations on the plant. These nutritional limitations may include nitrogen (N) because the amount of N in the compost application was smaller than that in the MAP application. In the compost alone treatment (equivalent rate of 33.4 t/ha of compost) an equivalent of 7.95 kg of mineral N per hectare was applied. By contrast, MAP at a rate of 91 kg/ha applied 9.10 kg ammonium N, representing an increase of 14% of applied mineral N. However, this result shows that in relative terms there are large reserves of P in the plant which can be mobilised at grain formation in the compost treated pots.

Parameter	Soil	Compost	Nutrient application (kg/ha)	
			Compost	MAP
Ammonium Nitrogen (mg/Kg)	4	40	1.34	9.10
Nitrate Nitrogen (mg/Kg)	3	198	6.61	
Sulphur (mg/Kg)	2.88	327	10.92	1.37
Potassium Colwell (mg/Kg)	315	13250	411	
Phosphorus Colwell (mg/Kg)	11	597	19.94	19.11
Phosphorus Retention Index	31.6	< 0.00		
Phosphorus Buffering Index	62.2	213		
Total Phosphorus (mg/Kg)	277	4952	165	
Organic Carbon (%)	3.44	8.88		
Conductivity (dS/m)	0.052	3.66		
pH ($CaCl_2$) (1:5)	4.70	7.60		
pH (H_2O) (1:5)	5.70	8.40		

Table 1 Chemical properties of soil and compost used in glasshouse pot trial.

Table 2 Total Dry Matter Yield of above and below ground plant material; Initial P = soil P + P applied as fertiliser prior to sowing; P uptake = Total P in above and below ground plant material; Uptake efficiency = P uptake/Initial P; Utilisation efficiency = DMY/P uptake. Data designated with different letters within each column are significant different at P<0.01.

	DMY	Initial P	P uptake	Uptake efficiency	Utilisation efficiency
	g/pot	mg P/pot		mg P uptake/ mg initial P	g DMY/ P uptake
20kg P/ha as MAP	8.8	51.5	9.4a	0.18a	0.94c
1:3 application of compost and MAP	9.3	51.5	11.2ab	0.22ab	0.86bc
1:1 application of compost and MAP	9.9	51.5	12.3bc	0.24b	0.80ab
3:1 application of compost and MAP	9.8	51.5	13.7c	0.27b	0.72a
20kg P/ha as compost	9.9	51.5	12.9bc	0.25b	0.78ab
Control	6.1	19.3	6.1	0.31	0.91
Microsoil straight	5.6	21.3	6.3	0.30	0.89
10kg P/ha as MAP	6.9	35.4	7.9	0.22	0.87
Microsoil + 10kg P/ha MAP	6.4	37.4	6.7	0.18	0.96
10kg P/ha as compost	8.5	35.4	10.2	0.29	0.83
Microsoil + 10kg P/ha Compost	8.6	37.4	10.9	0.30	0.80
LSD	**1.8**	**-**	**2.5**	**0.06**	**0.14**

The capacity to examine long term use was beyond the scope of this project, however, through long term trials it would be possible to determine the reduced application requirement of synthetic P fertiliser over time through the use of compost. A detailed evaluation of a local community's propensity to adopt compost would be an important area for further investigation because the soil chemistry associated with the efficient management of nutrients is only one part of the process of adoption of nutrient efficient farming practices.

The paired comparison of treatments with, and without, Microsoil in Table 2 show that when used under optimal glasshouse conditions Microsoil did not affect results. This is not very promising as even positive results in the greenhouse studies using inoculums rarely translate to positive field outcomes (Evans and Condon 2009). Therefore the use of microbial inoculants, like Microsoil, in combination with MAP or compost may not enhance P efficacy in order to grow more food. In contrast, results showed that co-application of compost and MAP did increase efficacy which could lead to greater crop yields, or the same amount of food with less inputs.

Acknowledgements

Funding for this project was provided by the Grains Research and Development Corporation, E.H Graham Centre for Agricultural Innovation (NSW Department of Primary Industries and Charles Sturt University), and Charles Sturt University.

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