Banded application improves the recovery of phosphorus fertiliser in a temperate pasture sward containing red clover

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Abstract

Phosphorus (P) fertiliser is commonly broadcast onto existing pasture swards for ease and cost of application. However, improvements in P acquisition efficiency may be achieved by banding fertiliser. Micro-swards of red clover (*Trifolium pratense* L.) were grown in intact sandy loam soil cores with a ^{33}P-labelled fertiliser source. Dissolved P fertiliser was applied either to the surface or at a depth of 30 mm, to either small or large volumes of soil. Growth rates were modest and significant differences were not observed for shoot yield among treatments. However, shoot P content and P recovery were 37% and 35% higher, respectively, when P fertiliser was distributed across a larger soil volume when compared to concentrated points. Similarly, banded treatments increased recovery by 40% compared to surface-applied fertiliser. The results suggested that banded application of a low concentration liquid P fertiliser may improve the recovery of P fertiliser by pasture legumes grown in soil with a low phosphorus buffering index (PBI).

Key Words

Trifolium pratense L., ^{33}P-radioisotope, stratification, subsurface

Introduction

Phosphorus fertiliser is commonly broadcast onto the surface of existing pasture swards for ease and cost of application. However, this results in the majority of P accumulating in the surface 2–4 cm of soil (McLaughlin *et al.* 2011). Surface drying may, consequently, lead to reduced P availability for plant uptake (Pinkerton and Simpson 1986). Subsurface placement has been suggested as an alternative to broadcasting fertiliser because the P fertiliser is placed where there is a greater chance of soil moisture interaction. Banding also reduces the contact between fertiliser and soil, thereby reducing P sorption (Malhi *et al.* 2001). Subsurface P fertiliser application may, therefore, increase the P acquisition efficiency of applied fertiliser and consequently reduce fertiliser requirements. As the price of P inputs increase, the potential improvements in use efficiency may offset additional application expenses.

The success of subsurface P fertiliser placement appears to be largely dependent on plant root morphology to ensure sufficient acquisition of available nutrients. For example, species with a fibrous root system (e.g. temperate pasture grasses) comprising long roots and long root hairs have a competitive advantage for P uptake, in contrast to leguminous species (e.g. *Trifolium* spp.) which have short, thick roots and short root hairs (Evans 1977). Furthermore, leguminous species generally exhibit a lower level of root plasticity (Hill *et al.* 2006; Haling *et al.* 2016), and their root proliferation within the vicinity of high P may be limited. These differences among species may influence the benefit of subsurface P placement, and fertiliser placement strategies may influence the composition of the pasture sward. Specifically, leguminous pasture species may not respond efficiently to narrow bands of highly concentrated P fertiliser.

This study sought to determine if subsurface placement of P fertiliser into intact soil cores containing red clover would improve; i) total shoot yield, ii) shoot P content, and iii) P recovery from a ^{33}P-labelled fertiliser.

Methods

Soil treatments and plant growth

Intact soil cores (cylindrical PVC pots; 100 mm diameter; 250 mm height) were taken from an established temperate pasture sward near Armidale, Australia. The sandy loam soil had low native P fertility (1.8 mg P kg^{-1}; Colwell 1963) and a low PBI (29; Burkitt *et al.* 2008). Each intact core contained at least one mature red clover (*Trifolium pratense* L.) plant, along with constituent temperate grass species. After collection of the cores, shoot biomass was cut to 20 mm height and additional red clover plants were established by sowing *T. pratense* L. cv. USA seed to increase the proportion of clover in the sward. Basal nutrients including potassium sulfate, boron and molybdenum were also applied. The intact soil cores were then watered to 80% gravimetric water content while the composition of the pasture swards stabilised. The swards were grown under natural lighting in a glasshouse (15–25°C) between April 2016 and August 2016 at Armidale.

After 55 days' growth, shoot biomass was cut and the P fertilised treatments were applied. There were two placement treatments, which simulated either a broadcast application (P placed on the soil surface) or a banded application (P injected 30 mm below the soil surface). These two treatments were combined with two concentration treatments, in which the proportion of soil volume enriched varied by applying the P fertiliser as either two points of high concentration P fertiliser or ten points of low concentration P fertiliser. In addition, there was a completely diffuse treatment of very low concentration P fertiliser which was applied as ten points each at the soil surface, 15 mm and 30 mm depth. Each P fertilised treatment received a total of 10 mg P core^{-1} of KH_2PO_4 labelled with 3.6 MBq core^{-1} of ^{33}P-radioisotope tracer. A control treatment was included which received no application of P fertiliser and there were four replicates of each treatment. Water was applied to the base of the intact soil cores, which simulated a period between rainfall events where shoot growth relied on stored soil moisture.

Harvest and analysis

The first harvest occurred 37 days after the P fertiliser treatments were applied. Shoot biomass was cut at 20 mm height and the proportion of grass, clover and broadleaf weed components were estimated. The shoot biomass was dried to determine dry mass before samples were digested using nitric acid. Digested samples were analysed for nutrient concentrations using ICP-OES and ^{33}P-radioisotope activity was determined by liquid scintillation counting. The same procedures were followed for the second harvest, which occurred 86 days after P fertiliser application. Data was analysed using a two-way ANOVA in R (R Core Team 2018), and contrasts were used to compare the overall differences between placement and concentration treatments. Total shoot biomass included the cumulative data from both harvests.

Results

Shoot dry mass was not significantly different among the six treatments (Fig. 1). This observation was consistent for both the first harvest ($P > 0.05$) and the cumulative data from both harvest periods ($P > 0.05$). The average pasture growth rate of all treatments during the experimental period was 0.022 g DM core^{-1} day^{-1}. Sward composition changed from predominately red clover to a grass/broadleaf weed mix. On average, the red clover component reduced from 79% to 31%, whereas the grass and broadleaf weed components increased from 17% to 34% and 4% to 35 %, respectively (data not shown).

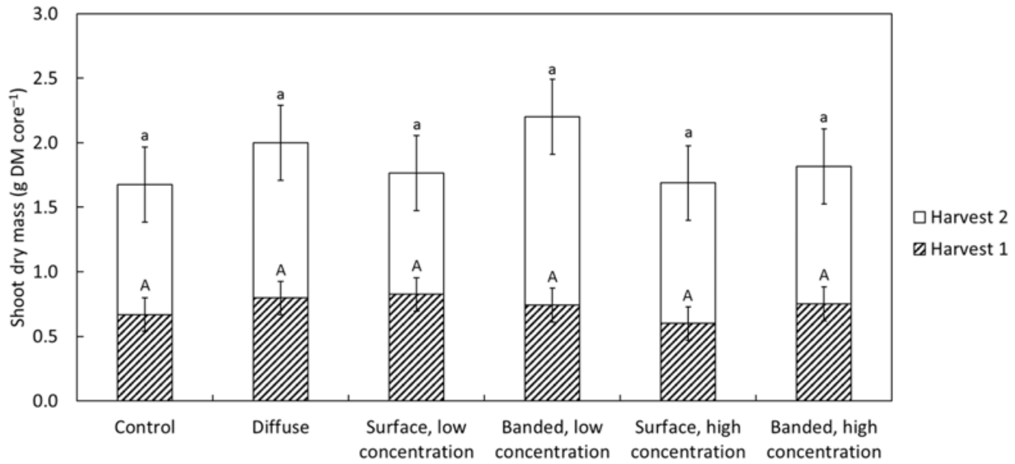

Figure 1. Shoot dry mass for harvest one and harvest two, taken 37 and 86 days after P fertiliser treatment application, respectively. Error bars represent standard error of the mean (n = 4) for harvest one, while error bars for harvest two represent standard error of the mean (n = 4) for the cumulative data. Treatments of the same harvest with the same letter are not significantly different at $P = 0.05$.

Shoot P content was on average 37% higher ($P < 0.01$) for the low concentration treatments compared to the high concentration treatments, at 0.85 g P core^{-1} and 0.59 g P core^{-1}, respectively. The diffuse treatment achieved a comparable shoot P content to the low concentration treatments. In contrast, significant differences were not observed for shoot P content between the banded and surface applied treatments ($P > 0.05$) (Fig. 2).

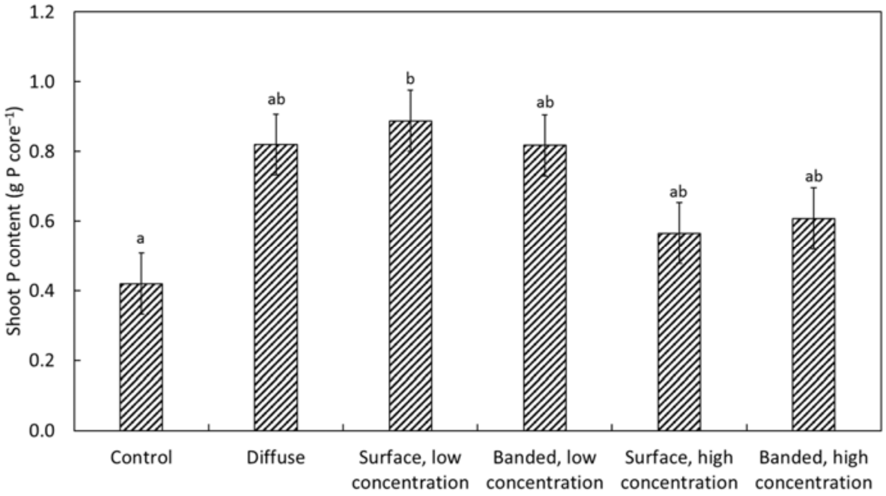

Figure 2. Shoot phosphorus (P) content for the entire experimental period of 86 days. Error bars represent standard error of the mean (n = 4) for the cumulative data. Treatments with the same letter are not significantly different at *P* = 0.05.

Phosphorus recovery of the banded treatments was on average 40% higher (*P* < 0.01) than surface applied treatments, with an additional 0.37% of the ^{33}P-labelled fertiliser recovered when banded. Similarly, the P recovery of the low concentration treatments was on average 35% higher (*P* < 0.01) than the high concentration treatments, by 0.32% of P derived from the ^{33}P-labelled fertiliser (Fig. 3).

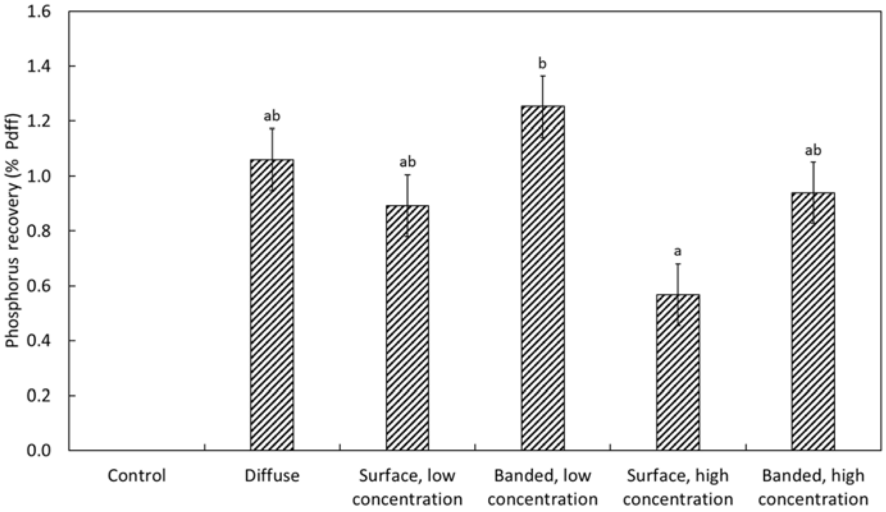

Figure 3. The fraction of shoot phosphorus (P) content derived from the ^{33}P-labelled fertiliser (% Pdff), referred to as P recovery, for the entire experimental period of 86 days. Error bars represent standard error of the mean (n = 4) for the cumulative data. Treatments with the same letter are not significantly different at *P* = 0.05.

Discussion

Slow pasture growth rates restricted the differences observed among P fertiliser treatments for total shoot yield during this relatively short trial. Slow growth combined with the short experiment may have contributed to the relatively low shoot P content and P recovery observed in all treatments. However, significant differences were still apparent for shoot P content and P recovery from the applied P fertiliser. In particular, the 40% difference observed between banded and broadcast application for P recovery suggested that subsurface application is an effective method for improving P fertiliser recovery in a temperate pasture sward. Under dry surface soil conditions, P acquisition may be increased by subsurface placement because there is a greater chance of soil moisture interaction at depth contributing to improved P availability (McLaughlin *et al.* 2011).

Volume enrichment is important for maximising P acquisition from low P sorbing soils. This volume effect was demonstrated by the 35% difference observed for P recovery and the 37% difference observed for shoot P content, between the low and high concentration P fertiliser treatments. Increasing the proportion of volume enriched by using a low concentration fertiliser may, therefore, be a viable strategy for increasing the interception of P fertiliser by plant roots. For example, pasture legumes such as *Trifolium* spp. have short, thick roots and short root hairs compared to temperate grass species (Evans 1977; Hill *et al.* 2006). These root traits limit the exploration of soil for nutrients such as P (Richardson *et al.* 2009). It is expected that increased volume of enrichment would enhance P acquisition by these legume species which have intrinsically poor root morphology traits.

Conclusion

Broadcast application of P fertiliser onto existing pasture swards is currently the most economically viable application method. However, subsurface placement of a low concentration liquid P fertiliser may improve the uptake and recovery of P by legume pastures in a low PBI soil. Further research is required to determine the economic viability of subsurface P fertiliser placement into existing temperate pasture swards, and the optimal concentration of P in liquid sources appropriate for each soil type. Economic viability will be primarily determined by the cost of P fertiliser, however improvements to placement techniques will also be important. Both aspects will influence the relative benefit of improvements in P recovery.

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