UTILISATION OF NITROGEN FROM PLANT RESIDUES AND FERTILISERS BY WHEAT IN CENTRAL QUEENSLAND FARMING SYSTEMS

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Summary. A field experiment on a cracking clay soil at Emerald, Central Queensland studied the effectiveness of plant residues and fertiliser (ammonium sulphate) in supplying nitrogen (N) to a wheat crop. ^{15}N labelled shoot residues of *Desmanthus virgatus* cv. Marc and grain sorghum (*Sorghum bicolor*), and ^{15}N ammonium sulphate fertiliser were added to microplots and the distribution of N in the soil/plant system traced over 219 days. Uptake of both sources of plant residue N by the wheat crop was less than for fertiliser at all samplings; at maturity less than 5% of N in wheat was recovered from the plant residues compared with 35% for the fertiliser. The plant residues maintained very low concentrations of mineral N ($NH_4 + NO_3$) in the soil compared with fertiliser N, but soil microbial biomass N was increased following application of the residues

INTRODUCTION

The feasibility of using pasture-ley legumes to reverse declining soil fertility in grain production systems of the northern cereal belt will depend in part on the efficiency of use of nitrogen (N) derived from legumes compared to that derived from fertiliser. This efficiency will be a function of both the rate of utilisation of this N by cereal crops and also the proportion of the N source lost from the plant/soil system by leaching etc. Although the efficiency of N fertilisers in the Central Queensland environment has been studied (1), there are no comparable data for the use of legume N sources in this semi-arid, sub-tropical environment.

MATERIALS AND METHODS

Design

The trial consisted of 3 treatments (shoot material of grain sorghum and *Desmanthus virgatus* cv. Marc, and ammonium sulphate fertiliser), 7 sampling times (0, 19, 34, 55, 75, 109, 155 and 219 days after inserting rings), and 4 replicates. Shoot residues were added at a rate of 2250 kg dry matter/ha which contained 34 kg N/ha for sorghum (1.5% N and 17.3% ^{15}N a.e.) and 67.5 kg N/ha for *Desmanthus* (3.0% N and 16.0% ^{15}N a.e.). The N fertiliser $(NH_4)_2SO_4$ (21.2% N , 10% a.e.) was added at a rate of 50 kg N/ha.

Preparation of Residues/ Field trial

^{15}N labelled residues were prepared by regularly adding approximately 30% a.e. $(^{15}NH_4)_2SO_4$ solution to pots containing cracking clay soil similar to that used in the field trial. The legume was not inoculated so as to maximise the ^{15}N enrichment. After 37 days (for sorghum (MR40)) and 40 days (*Desmanthus virgatus* cv. Marc) shoots were cut at ground level, dried for several days at 50^{o}C, and stored in a sealed plastic bag.

The trial site was planted either to *Desmanthus virgatus* (cv. Marc) or grain sorghum (MR40) in late October 1993. On 23/3/95, the sorghum grain was harvested and the remaining sorghum stover was removed with a forage harvester. Legume dry matter was retained in-situ. All plots were scarified and then harrowed. In each plot, seven 350 mm lengths of PVC tube (100 mm diameter) were inserted 300 mm into the soil on the 21 April 1994 and a pooled soil sample from each treatment retained for soil analysis. Plant residues were applied to the soil surface and a piece of shade cloth placed over them to prevent physical loss of residues. Wheat (cv. Hartog) was planted on the 26 May 1994 and subsequently thinned to one seedling per tube. The ^{15}N fertiliser was added to the appropriate rings at wheat planting. Differences in timing of application of the fertiliser and residue treatments was done to simulate field

conditions viz. residues from a previous crop/pasture having time to decompose prior to sufficient rain occurring to permit planting, whereas fertiliser tends to be added at sowing. One ring from each treatment were sampled on 11 May, 26 May, 16 June, 6 July, 10 August , 23 September and 8 December 1995. Irrigation was applied three times in-crop (total 100 mm).

Data collection

At each harvest, wheat seedlings were cut at the base of the plant, dried at 70^{o}C, before weighing and grinding prior to chemical analysis. The PVC tube was removed from the ground and subsequently divided into 0-10, 10-20 and 20-30 cm layers. A single core (1.75 cm diameter) was taken from the 30-60, 60-90 and 90-120 cm depths. Soil in the 0-10 and 10-20 cm layers was weighed, and subdivided into two: one sample was stored at 4^{o}C and retained for mineral and biomass N analysis; the other half (together with soil from the other layers) was oven dried at 40^{o}C, ground (<200 µm), and analysed for total ^{14}N and ^{15}N. Soil moisture content (105^{o}C) was determined and all data were calculated on an o.d. basis. Soil microbial biomass N was determined as ninhydrin-positive compounds (NPC) following fumigation with $CHCl_3$ using a factor of 3.5 to convert NPC to biomass-N (3). ^{15}N natural abundance in the mineral N and biomass pools were determined using a diffusion technique to transfer N to an acidified filter paper disc prior to analysis by mass spectrometer. ^{14}N and ^{15}N contents of soil and plant material were directly assessed using a *Roboprep* sample converter followed by analysis on a *Tracermass* mass spectrometer.

RESULTS

During the experiment, no significant effects of the added N sources were found in soils below 10 cm depth.

Soil mineral N in the 0-10cm layer following addition of the plant residues remained low throughout the season and less than 4% of the added residue N (as indicated by ^{15}N) was found in the mineral N pool at any sampling. Application of fertiliser raised soil mineral N in the 0-10 cm layer and although it declined through time, presumably due to crop uptake, it remained higher than for the residue treatments (Fig. 1). Over 88% of the fertiliser ^{15}N was recovered in the mineral N pool soon after the fertiliser was added, and 33% was still present as mineral N at grain maturity.

Soil microbial biomass increased following the application of both plant residues ($p<0.05$) and remained higher than for the fertiliser treatment during the growth of the crop (Fig. 1). Approximately 20% of the ^{15}N added in plant residues was found in the microbial biomass pool, with little indication that the amount present in this form varied through time (data not shown).

Plant dry matter yields and N uptakes were not affected by N source (data not presented). Fig. 2 shows that the recovery of ^{15}N from the sources in the wheat crop and soil. A significantly

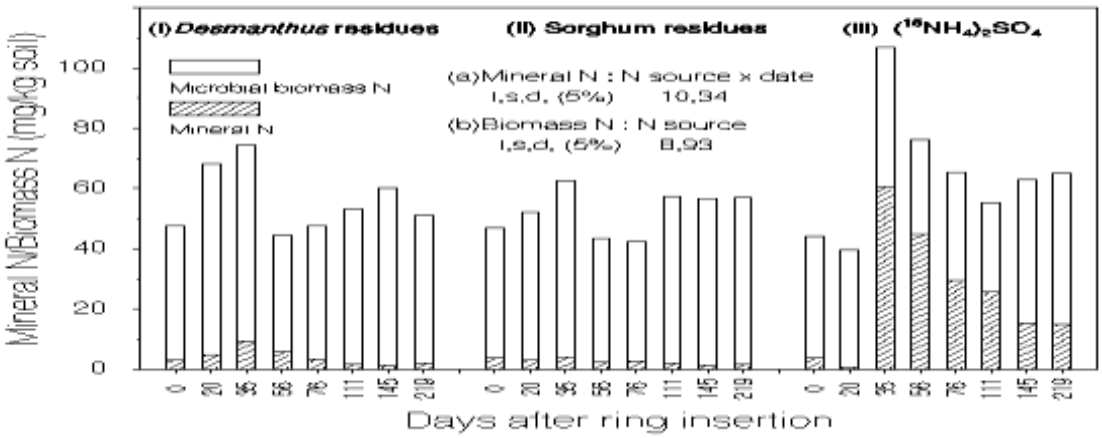

Figure 1. Changes in mineral N (NO_3 + NH_4) and microbial biomass N over time for *Desmanthus virgatus*, sorghum and ammonium sulphate fertiliser N sources.

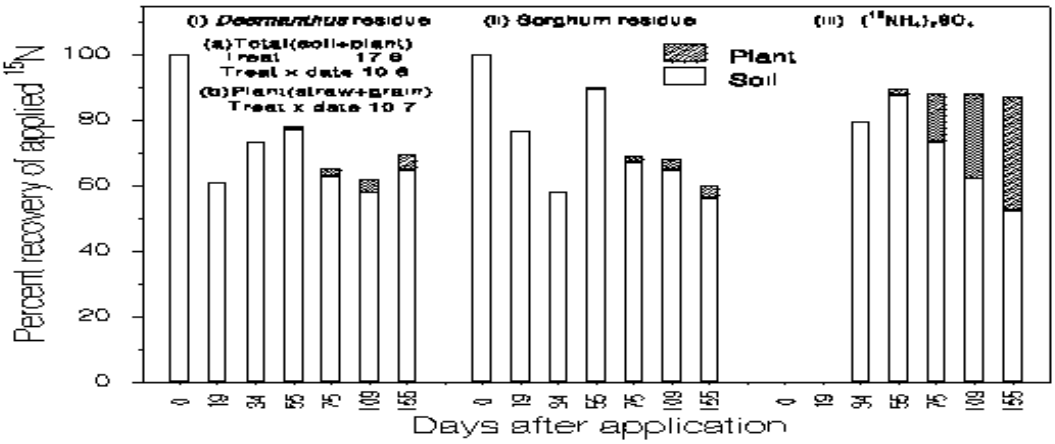

Figure 2. Recovery of N derived from either *Desmanthus virgatus*, sorghum or ammonium sulphate fertiliser in wheat and soil at Emerald, 1994.

higher proportion ($p<0.05$) of ^{15}N applied as fertiliser was taken up by the crop than from the crop residues at all harvests. The recovery of residue N in the crop at maturity was only 5% compared with 35% for the fertiliser source. Although total recoveries of ^{15}N in plant and soil were significantly less than (100%) (Fig. 2), the incomplete recovery does not invalidate the poorer effectiveness of plant residue N in contributing to N uptake by the crop.

DISCUSSION

The ability of a pasture-ley farming system to arrest soil fertility (N) decline in the Central Queensland will in part depend on how efficiently the legume N can be used by subsequent cereal crops. In this study, conducted only over a single limited time span, N derived from both legume (*Desmanthus virgatus*) and cereal (sorghum) residues provided little N to a following cereal crop (wheat), compared to an inorganic fertiliser source, ammonium sulphate. Although the legume N source contained a greater amount of N (67 kg N/ha) compared to the fertiliser (50 kg N/ha), the cereal derived a much higher proportion of its N from the fertiliser. Other studies in both temperate climates (2) and tropical regions (4) have also found that inorganic fertilisers can provide much more N than legume residues in the first season after application although this advantage disappears in the following seasons.

The lower effectiveness of residue N in supplying N to the crop is supported by the small effect of the residues on the mineral N present in the soil and the small proportion of the residue ^{15}N that was found in the mineral N pool. However the application of residues did increase the size of the soil microbial biomass pool and experimentation is continuing to examine the longer term consequences of this in terms of the N supply capacity of these systems. At present we have no satisfactory explaination for the incomplete recovery of applied ^{15}N in this experiment. No ^{15}N was found in deeper soil layers suggesting that leaching was not the cause. Soil moisture would have been high following irrigations, but it seems dubious whether enough NO_3 was ever present in the soils following residue application to have caused major losses via denitrification.

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