MANAGING NITROGEN IN CROPPING SYSTEMS FOLLOWING LEGUME LEYS

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Summary. Field experiments were conducted at three locations on Open Downs grey clay in the Roma area of Southern Queensland to confirm, quantify and minimise denitrification losses following medic, lucerne and Mitchell grass/medic leys. Net nitrate accumulation over the 20 months following leys was in excess of average wheat cropping requirements, rendering the excess prone to loss. Denitrification was measured under zero-till conditions using a ^{15}N mass balance technique in microplots confined to 250 mm depth. Cumulative losses from denitrification measured over the 20 month trial period, indicated that 98%, 84% and all (124%) of nitrate present at trial commencement would have been lost following medic, lucerne and grass/medic leys respectively. Growing forage sorghum after a ley was very effective in immobilising excess soil nitrate thus preventing its irretrievable loss. Zero-tillage appeared to delay nitrate appearance only when a grass was present in the former ley.

INTRODUCTION

The introduction of legume-based ley pastures is a successful technique for restoring soil nitrogen fertility to degraded cropping soils in Southern Queensland (Dalal, pers. commun.). Rapid mineralisation of highly labile legume residues following a ley can lead to large accumulations of available nitrogen that may be well in excess of crop requirements. If this nitrogen is lost through processes such as leaching and denitrification the rate of fertility decline following a ley may be rapid.

Denitrification losses are of particular concern as all pre-requisites for denitrification are present in this region, particularly during summer. These include warm soil temperatures, an alkaline soil reaction, soils prone to surface saturation from predominantly summer rainfall and sources of carbon and nitrate from ley residues. These last two provide respectively metabolisable substrate and an oxygen source for denitrifying soil micro-organisms. Losses of over 80% of available nitrate (1) have been recorded from a single saturation event following a legume-grass ley on a Vertisol in southern Queensland.

This study sought to confirm and quantify field denitrification losses following various pasture leys .We also investigated various management strategies that could be used to minimise nitrogen losses in the immediate post-ley period and so extend the cropping phase by improving nitrogen supply to crops in later years.

MATERIALS AND METHODS

Leys of lucerne, cv. Trifecta, medic cv. Sava and a mixed Mitchell grass (*Astrebla sp*.) naturalised medic (*Medicago polymorpha*) pasture were used in this experiment. They were located on Open Downs grey cracking clay (Ug 5.22) (2) at three different sites in the Roma area of southern Queensland. The lucerne and medic leys were each four years old and followed periods of cultivation, while the grass-medic pasture had been present for at least 20 years.

Denitrification

Denitrification was measured under zero-till conditions following each of the respective leys over four consecutive periods from 11 February 1993 to 31 August 1994. A ^{15}N mass balance technique was used. Cylindrical plastic enclosures of 235 mm internal diameter were pressed into the soil to 250 mm depth with 50 mm left protruding above the soil surface. ^{15}N labelled potassium nitrate (74 atom % excess) at the rate of 40 kg N/ha was applied uniformly to soil in the enclosure at 50 mm depth. Potassium bromide was also applied at 100 kg Br/ha as a proxy for nitrate to determine the extent of any leaching losses. At the conclusion of each time period, enclosures were excavated and remaining ^{15}N and bromide measured and denitrification and leaching losses estimated.

Managing nitrate losses

Various strategies were used to minimise nitrate loss following the various leys. These were based on minimising nitrate mineralisation from ley residues and assimilating excess soil nitrate back into crops to prevent denitrification losses.

Specifically strategies included:

- using zero tillage to delay appearance of nitrate from ley residues
- returning slowly mineralisable (high C:N ratio) grass as a component of ley residues
- growing forage sorghum immediately after ley termination to assimilate surplus nitrate and to slow subsequent nitrogen turnover

Other strategies using winter crops were implemented, however extensive drought during 1992-94 caused winter crops to fail, so these strategies are not described.

Baseline treatments of continuous cultivated fallow, continuous zero till and continuing pasture ley were maintained from 17 November 1992 to 17 August 1994. Forage sorghum (cv. Jumbo) was planted into cultivated fallow over the summers of 1993 and 1994. All treatments above were replicated four times at each site. Soil nitrate (0-120 cm) was measured on seven occasions during the experiment, however data on only the first and last of these are presented.

RESULTS AND DISCUSSION

Denitrification

Table 1 shows denitrification and nitrogen leaching over essentially three periods of drought (periods 1, 2 and 4) and one period of above average summer rainfall (period 3). Notable were the often considerable denitrification losses from brief surface saturation events during drought periods. In the wetter period from 24 November 1993 to 17 March 1994, some nitrate may have been protected from denitrification by leaching below 250 mm. Hence the low percentage loss of applied ^{15}N associated with high losses of unleached nitrate. However displacement of nitrogen by leaching as estimated by bromide gives no information on nitrate denitrified during the leaching process or nitrate denitrified below 250 mm. Denitrification may therefore have been underestimated over this period.

Cumulative losses from denitrification measured over the 20 month trial period, indicated that 98%, 84% and all (124%) of nitrate present at trial commencement would have been lost following medic, lucerne and grass/medic leys respectively. Loss of nitrogen mineralised during the trial would also have been substantial. Management techniques to minimise such losses are therefore likely to be of considerable value.

Table 1. Field denitrification (mass balance method) and leaching[a] displacement of applied ^{15}N fertiliser from zero-tilled soil for four consecutive periods following various pasture leys in the Roma area.

Time period	Previous ley pasture	Denitrification loss of applied N	Denitrification loss of unleached N	Leaching of N below 250 mm	Period rainfall

		(%)	(%)	(%)	(mm)
11 Feb 93	Medic	12	12	0	86
to	Lucerne	16	16	0	71
3 Aug 93	Grass/medic	38	38	0	122
	l.s.d.	5	5	0	
3 Aug 93	Medic	48	48	0	140
to	Lucerne	36	36	0	134
24 Nov 93	Grass/medic	51	51	0	132
	l.s.d.	8	8	0	
24 Nov 93	Medic	23	89	74	342
to	Lucerne	17	73	77	405
17 March 94	Grass/medic	16	82	81	397
	l.s.d.	10	27	6	
17 March 94	Medic	15	16	5	31
to	Lucerne	15	16	3	31
31 Aug 94	Grass/medic	19	20	6	36
	l.s.d.	10	8	7	

[a] Estimated by leaching of bromide.

Managing nitrate loss

Table 2 provides nitrate nitrogen data from approximately one month (depending on site) after treatment implementation and 20 months later.

Table 2. Soil nitrate nitrogen (0-120 cm) following three pasture leys for various treatments one month and twenty months after experiment commencement.

Previous ley pasture	Treatment	Soil nitrate nitrogen (kg/ha, 0-120 cm) December 1992	August 1994
Medic	Conventional tillage (CT)	23	169
	Zero tillage (ZT)	29	142
	Continuing ley	29	54
	Forage sorghum	23	16

Lucerne	Conventional tillage (CT)	26	182
	Zero tillage (ZT)	22	158
	Continuing ley	22	18
	Forage sorghum	26	19
Grass/medic	Conventional tillage (CT)	38	194
	Zero tillage (ZT)	36	131
	Continuing ley	36	53
	Forage sorghum	38	38
l.s.d.		12	54

Mineralisation of nitrogen was considerable in CT and ZT treatments from all previous leys. Considering that these values represent net mineralisation and include the considerable denitrification losses shown in Table 1, it is apparent that actual mineralisation rates following leys would have been substantially higher. Certainly net nitrogen mineralised was more than sufficient to support two average wheat crops (60 kg N/ha at planting for each) that might have been grown over the trial period if more favourable conditions had prevailed.

There was a trend for CT to mineralise more nitrate than ZT. With the grass/medic ley the difference was significant but not with the pure legume leys of medic and lucerne. Presumably rapid mineralisation of highly labile low C:N ratio, pure legume residues is less likely to be influenced by tillage, whereas the grass component in the grass/medic ley, having higher C:N ratio residues, has probably been slower to decompose under ZT. The 63 kg N/ha difference retained with ZT after the grass/medic ley would be sufficient to grow an additional average wheat crop at Roma if this nitrogen were to be released later in the cropping cycle.

Forage sorghum was grown in 1992-93 and 1993-94 with the intention of assimilating the expected large quantities of available soil nitrate following leys. Drought in the summer of 1992-93 resulted in failure of the first crop, however in 1993-94, crops accumulated 9.2-12.6 t/ha of above ground dry matter, assimilating 116-142 kg/ha of soil mineral nitrogen. This uptake is reflected in the relatively low soil nitrate nitrogen values in August 1994 after forage sorghum shown in Table 2. Sorghum was therefore successful in immobilising excess soil nitrate from the soil, thereby preventing possible denitrification.

In this role, crops such as grain or forage sorghum might be considered the final phase of a pure legume ley, taking the role of grass (in the grass/legume ley) in assimilating nitrate mineralised from highly labile legume residues and storing this nitrogen in a less mineralisable form to be metered out during a subsequent cropping phase. If forage sorghum prevented up to 142 kg N/ha from being denitrified, it would have saved sufficient nitrogen to produce up to two average wheat crops in Roma.

CONCLUSION

Nitrate accumulated over 20 months following lucerne, medic and medic/grass leys was in excess of immediate crop requirements. Denitrification caused large and wasteful losses of nitrate following leys. Strategies such as the timely planting of high nitrogen capacity crops such as forage sorghum and to a smaller extent the use of ZT after leys assisted in reducing nitrate loss by retaining nitrogen in organic forms that are not subject to denitrification. Saved organic nitrogen may be mineralised later in a post-ley, cropping phase allowing that phase to be extended.

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