Nitrogen fixation and soil nitrogen in organic ley arable rotations

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ABSTRACT

Nitrogen (N) fixation in a white clover/ryegrass mixture was measured in 1,2,3 and 4-year-old organically managed leys during 2000. N fixation varied between 73.7 in 1-year-old leys and 33.5 kg ha^{-1} in 4-year-old leys. Soil nitrate-N, grass N yield and N content of grass and clover were all lowest in 2-year-old leys and highest in 3-year-old leys. The proportion of clover nitrogen derived from the atmosphere (pNdfa) was significantly lower in 3-year-old leys.

Keywords: organic farming; white clover; ley-arable rotation, soil nitrogen, nitrogen fixation

INTRODUCTION

Organic farms in the UK use symbiotic N fixation by grass-white clover leys as their principle source of nitrogen (Lampkin 1990). Clover yields, the concentration of N in the clover and the proportion of clover N derived from the atmosphere (pNdfa) all vary with management and climate, making it difficult to predict N fixation. High levels of soil N have been shown to reduce the pNdfa of white clover and increase the grass:clover ratio (e.g. Høgh-Jensen and Schjoerring, 1994). The aim of this study was to quantify rates of N fixation in organically managed leys and to examine the relationship between fixation and soil nitrate concentrations.

MATERIALS AND METHODS

The study was carried out on the Tulloch Organic Farm at SAC Aberdeen (grid reference NJ 845095), which covers 65.8 ha of exposed, marginal land on sandy loam soil. Experimental plots of perennial ryegrass/timothy/white clover have been established providing leys of different ages: four 1-year-old, four 2-year-old, four 3-year-old and two 4-year old leys. 1-year-old leys were grazed while all of the 2-year and 4-year-old leys, and half of the 3-year-old leys were cut for silage and had between 10 and 23 t ha^{-1} of farmyard manure applied in spring.

Three subplots (0.5m x 0.5m) were chosen in each plot, and in control areas containing no clover. These were covered with cages to prevent grazing. Labelled ^{15}N fertiliser (($^{15}NH_4)_2(SO_4$) at 10 % ^{15}N) was applied at a rate of 5 kg N ha^{-1} using a watering can, and watered in with deionised water. Applications of labelled N were made every four weeks, between 22nd May and 19th October.

Herbage was sampled to ground level prior to each labelling, separated into grass + weeds and clover, dried overnight at 80^{o}C and weighed. The dried samples were then ball milled and their ^{15}N isotopic enrichment was analysed by mass spectrometer (*Europa Scientific* Tracermass stable isotope analyser). The percentage of clover Nitrogen derived from the atmosphere (pNdfa) was calculated from: 1-(%excess ^{15}N in clover / %excess ^{15}N in the grass). N fixation was calculated from: N fixation = dry matter x %N in clover x pNdfa

Soil cores were taken to 0.15m depth from 8 random clover patches and 8 random grass patches in each plot, then bulked to give one sample from beneath clover and one sample from beneath grass per plot. Soil was sampled on 28th February, 6th April, 4th July, 27th September and 29th November 2000. K_2SO_4 extracts from each soil sample were analysed for nitrate using a mark II *Technicon* autonalyser.

Data was analysed by Residual Maximum Likelihood (REML) ANOVA and Kruskal-Wallis on Genstat and MINITAB. Nitrate data was transformed by log and fisher transformations.

RESULTS

There was significantly less N fixation ($p<0.05$) in 4-year-old leys (Table 1). To account for fixed nitrogen present in roots and stolons. The N yield of clover harvested prior to labelling varied from 36-57% of the total clover N yield. Assuming that pNdfa of clover was similar in May and June, the N fixation figures should therefore also be multiplied by a factor of c.1.4, as the data in Table 1 doesn't include any N fixation before June.

Table 1. N fixation and grass N yield

Age of ley	Above ground N-fixation June-October	Estimated annual N-fixation*	Grass %N	Grass N yield
1	73.7^{a} (23.0)	175.41 (54.74)	2.97^{a} (0.08)	103.5^{a} (14.1)
2	70.4^{a} (9.8)	167.55 (23.32)	2.59^{b} (0.09)	66.5^{b} (4.8)
3	69.2^{a} (10.7)	164.70 (25.47)	3.19^{a} (0.14)	126.1^{a} (17.2)
4	35.2^{b} (8.9)	83.78 (21.18)	2.99^{a} (0.61)	110.1^{a} (6.9)

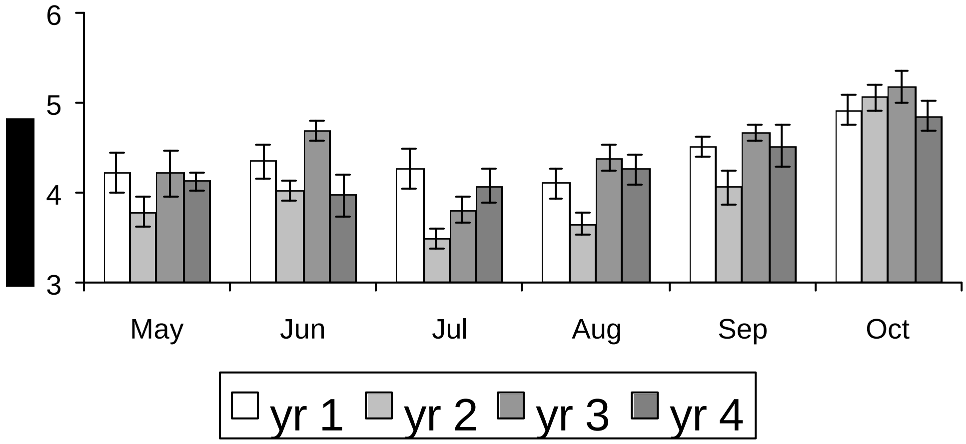
Numbers in brackets indicate standard errors. Numbers followed by the same letter are not significantly different at p=0.05

*Above ground figures were multiplied by 1.7 to account for fixed N below ground (Jorgensen and Ledgard, 1997)

The N content of clover (Figure 1) varied seasonally ($p<0.00001$) and also varied with age of ley ($p<0.00001$). There was a significant interaction between age of ley and date ($p<0.00001$) with older leys containing a lower N concentration than younger ones, late in the season. N content of grass varied seasonally ($p<0.0001$) and also varied with age of ley ($p<0.0001$, Table 1).

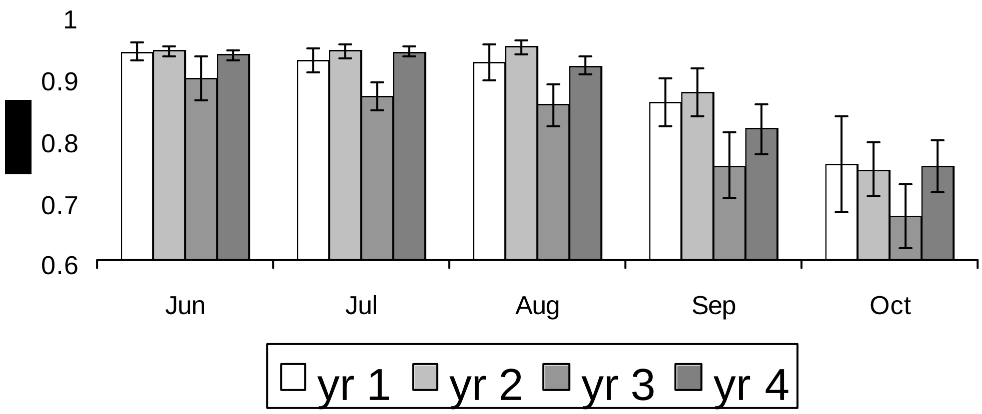
There was a significant interaction between age of ley and date ($p<0.0001$).

Figure 1 %N concentration of clover in different months and ages of ley



Clover pNdfa (Figure 2) varied seasonally (p<0.0001) and with age of ley (p<0.0001), the October values of pNdfa being around half of that measured in June and July

Figure 2 pNdfa of clover in different months and ages of ley 2000



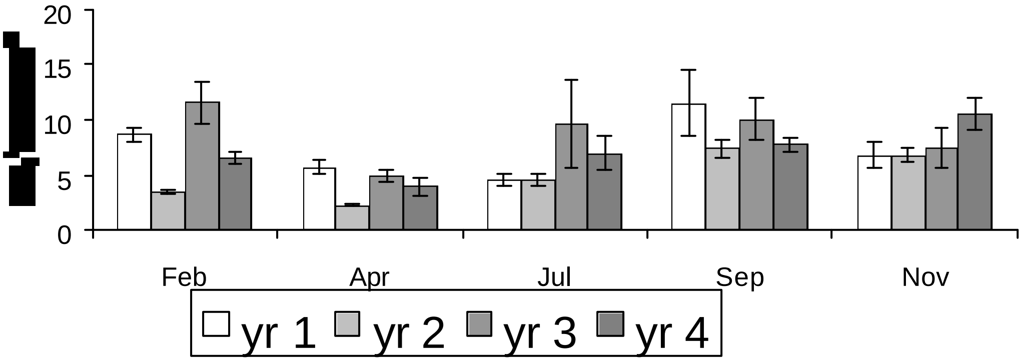
Soil nitrate N under clover (Figure 3) and under grass (Table 2) varied significantly with age of ley (p<0.01) and seasonally (p<0.01). Overall, there was no difference between nitrate levels under grass and clover patches, but there was a significant interaction between date and vegetation type (p<0.05) with higher nitrate under clover than grass in summer.

Table 2: Soil nitrate N under grass patches 2000

Age of ley	Feb	April	July	Sept	Nov
1	8.06 (1.35)	5.26 (1.93)	4.38 (1.86)	7.48 (3.00)	7.88 (4.07)
2	3.92 (0.39)	1.87 (0.35)	2.96 (0.70)	8.22 (3.55)	5.87 (0.90)
3	7.70 (1.33)	3.66 (2.03)	4.29 (0.65)	19.3 (6.78)	8.24 (1.36)
4	13.96 (18.8)	2.12 (0.42)	5.44 (1.76)	7.80 (3.71)	14.34 (2.76)

Numbers in brackets indicate standard errors

Figure 3 Soil Nitrate N under clover patches in different months and ages of ley 2000



DISCUSSION

Soil nitrate, grass N yield, grass N content and clover N content followed a similar pattern: lowest in 2-year-old leys and highest in 3 year old leys. pNdfa was lowest in 3-year-old leys, probably because of the high soil N. Previous data from this site (Sanders *et al* 2001) also showed high soil N in 3-year-old leys, and low clover N content in 2-year-old leys. Loisseau *et al.* (2001) observed 2 year cycles in the effect of soil N on grass and clover, and concluded that clover elevates soil N, benefiting grass. Grass then depletes soil N, benefiting clover, but it takes a year for these effects to become apparent in the vegetation.
Nitrate was higher under clover than under grass in July. This is in agreement with previous results from this site (Sanders *et al.* 2001). It is possible that fixed N is being transferred from clover to the soil, or alternatively clover may be less effective than grass at taking up nitrogen.

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REFERENCES

Hogh-Jensen H; Schjoerring JK (1994) Measurement of biological dinitrogen fixation in grassland: Comparison of the enriched 15N dilution and the natural 15N abundance methods at different nitrogen application rates and defoliation frequencies. Plant and Soil 166: 153-163

Jorgensen FV; Ledgard SF (1997) Contribution from stolons and roots to estimates of the total amount of N2 fixed by white clover (*Trifolium repens*). Annals of Botany 80: 641-648

Loisseau P; Soussana J-F; Loualt F; Delpy R 2001 Soil N contributes to the oscillations of the white clover content in mixed swards of perennial ryegrass under conditions that simulate grazing over five years Grass and Forage Science 56: 205-217

Sanders I, Watson CA, Rees R and Atkinson D (2001) Effects of ley arable rotation on soil nitrogen and nitrogen fixation. Aspects of Applied Biology 63: 61-66

From: Powell et al. (eds), *UK Organic Research 2002: Proceedings of the COR Conference, 26-28th March 2002, Aberystwyth*, pp. 85-88.