SOIL FERTILITY BUILDING CROPS IN ORGANIC FARMING

D. Hatch[1], A. Joynes[1], A. Stone[1] and G. Goodlass[2]
[1]Institute of Grassland and Environmental Research (IGER), North Wyke Research Station, Okehampton, Devon, UK. EX20 2SB. david.hatch@bbsrc.ac.uk
[2]ADAS, High Mowthorpe, Duggleby, Malton, North Yorkshire, UK. YO17 8BP

ABSTRACT

Nitrogen (N) fixation was estimated in organically managed red clover/grass plots with and without green manure (i.e. surface mulched) and/or the addition of well-composted farmyard manure (FYM) incorporated into the seedbed, which were then cut four times during the 2003 growing season. The FYM had a beneficial effect of increasing dry matter and N yields significantly at the first harvest, but the effect disappeared over subsequent harvests, suggesting that most of the N was in recalcitrant forms. Over the growing season, mulching did not affect red clover/grass dry matter or N yields, but did reduce the proportion of N fixed, from 40 kg N ha^{-1} to about half this amount, when compared with plots from which the clover/grass herbage was cut and removed.

INTRODUCTION

To be sustainable, organic farming needs to be self-sufficient in N, through the fixation of atmospheric nitrogen (N_2) by legumes, recycling of crop residues (green manures) and the application of animal manures, or composts. Only fixed N represents a true import of N onto the farm in this situation. Despite this reliance on legumes for N, much remains to be understood about how to maximise N_2 fixation and make the most efficient use of the fixed N. The availability of soil mineral N is generally thought to reduce the capacity to fix N_2 and soil N will be increased by manure applications, cutting and mulching, and grazing. Fixation tends to decrease with legume age, mainly because of a concomitant increase in soil N. The aim of this study is to establish the extent to which increased soil fertility, FYM applications and/or mulching, can adversely affect N_2 fixation.

MATERIALS AND METHODS

The study was carried out on a well drained, reddish gravely loamy soil over Permian breccia from the Crediton Series, a typical brown earth (FAO dystric or eutric cambisol, USDA dystrochrept or eutrochrept) at IGER, North Wyke in the South West of England. Further details of the soil characteristics are reported in Hatch et al. (1998). The existing grass/clover sward was destroyed by ploughing, followed by further cultivations, and then rolled to produce a fine seed bed. Forty eight paired plots (1.5 x 10m) were prepared for planting in autumn 2002, either with, or without composted FYM incorporated into the seed bed at a rate of 30 t ha^{-1} (supplying 170 kg total N ha^{-1}). The plots were randomised, and half were sown with red clover (*Trifolium pratense*, cv. Merviot), while the other half were sown with perennial ryegrass (*Lolium perenne* L.). Whereas, the sown ryegrass plots remained relatively weed-free, the clover plots included a high proportion of grasses (including some ryegrass) which regenerated from the existing seed bank. As the plots were to be managed organically, no herbicides were used and, therefore, these plots were effectively red clover/grass mixed swards. The plots were cut using a small plot harvester, four times during the growing season. To control annual weeds, an early season cut was taken and the herbage was removed, but in the remaining three harvests, the following mulching treatments were applied to selected plots: Unfertilized ryegrass only plots (herbage cut and removed) were employed to estimate the N supplying capacity of the soil, so that N_2 fixation in the clover/grass plots could be obtained by the differences in N yields. Additional unfertilized ryegrass plots (receiving mulch from the clover/grass plots) were used to assess the benefit of mulching plus soil N.

Treatments

A Red clover/grass mixture (herbage cut and removed)
B Ryegrass only (herbage cut and removed)
C Red clover/grass mixture (herbage cut and returned to plot)
D Ryegrass only (herbage cut and removed: herbage from treatment *A* spread on the plot)

The cut herbage (green manure) which was returned to the plots, was spread out to dry partially and then the plots were mown again, allowing the cuttings to fall on the sward as a fine mulch. There were six replicates of each treatment. Herbage samples were taken after each cut, assessed for dry matter yield (DM), ground and analysed for total C and total N (Carlo Erba elemental analyser). The herbage from the clover/grass plots was separated into clover, grass, weeds and dead material, then dried and weighed separately. The fractions were then recombined, ground and analysed for total C and N, as before.

Nitrogen accumulation below ground was determined by measuring the total N contained in roots from soil cores taken towards the end of 2003. Annual yields were determined by summing the yields from each harvest. Estimates of N_2 fixation were made by subtracting the N offtake found in the ryegrass only controls, from that found in the treatments containing red clover/grass. The experiment will be continued over two growing seasons to follow changes associated with increasing differences in soil fertility brought about by the different treatments. A second application of composted FYM (19 t ha^{-1}) was added in autumn 2003, as a top dressing to the FYM-treated plots, supplying a further 170 kg total N ha^{-1}.

RESULTS AND DISCUSSION

Dry matter yields

Treatment *B* (ryegrass control, cut and removed) provided an indication of the N supplying capacity of the soil, with annual DM yields of 7018 and 5921 kg ha^{-1} in plots with, or without

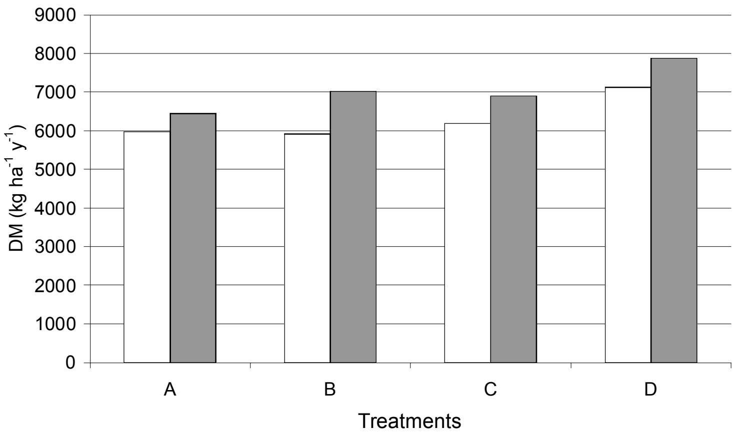

Figure 1. *Annual herbage dry matter yield. Open histograms: without FYM; shaded histograms: with FYM. Values are means of six replicates (SEM = ±228; LSD = 660).*

FYM, respectively However, treatment *D* (ryegrass with green manure) had significantly (P< 0.01) higher yields (from the benefit of mulching) of 7872 (with FYM) and 7129 (without FYM) kg ha^{-1} than treatments *A, B* and *C* (Fig.1). The effect of incorporating FYM in the seedbed improved yields (P= 0.005) in the 1st harvest (data not shown), but the effect did not persist in subsequent harvests, although there was a consistent trend for higher yields in all the treatments which had received FYM (Fig. 1).

Nitrogen yields

The available soil N, measured in N offtake from Treatment *B,* amounted to 110 and 129 kg N ha^{-1}, with or without FYM, respectively. Thus the well-composted FYM only provided an additional 19 kg N ha^{-1}, although it may also have had other benefits in terms of improving the general soil quality. There was a significant effect (P= 0.001) of FYM on N yield in the 1st harvest (data not shown) and, as with DM yields, a consistent, but non-significant trend for higher N offtakes in all treatments expressed on an annual basis. Treatments *A, C* and *D*, all had higher (P< 0.001) N offtakes than *B*, (Fig. 2), but there was no direct effect of FYM, and no interaction between FYM and the cutting/removing, or mulching treatments. The benefit to the grass only treatments (*D*) of mulching, compared with treatment *B*, amounted to an extra 25 kg N ha^{-1}, regardless of whether or not FYM had been supplied. Nitrogen offtake in the clover/grass treatments was not significantly different, whether the herbage was cut and removed (*A*), or mulched (*C*) and the amounts of N in the mixed swards was not different from the N recovered in the ryegrass only plots that had received the green manure (*D*).

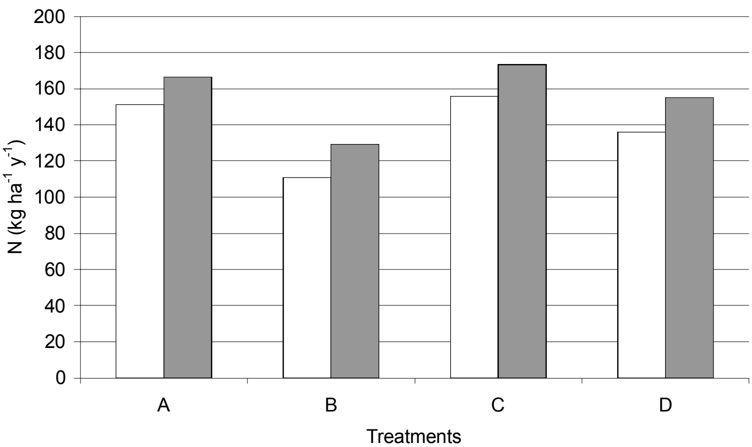

***Figure 2**. Annual nitrogen offtake. Open histograms: without FYM; shaded histograms: with FYM. Values are means of six replicates (SEM = ±5.53; LSD = 16).*

***Table 1**. Estimates of annual nitrogen (N_2) fixation from red clover/grass swards.*

N offtake of treatments minus ryegrass controls	Fixation N (kg ha^{-1} y^{-1})
FYM, clover cut and removed (*A-B*)	40.4
No FYM, clover cut and removed (*A-B*)	37.2
FYM, clover cut and returned to plot (*C-D*)	19.8
No FYM, clover cut and returned to plot (*C-D*)	18.4

Nitrogen fixation

Table 1 shows that the clover/grass plots with herbage cut and removed (treatment *A*) fixed ca. 40 kg N ha^{-1} y^{-1}, whilst the clover/grass plots that had the cut herbage returned as a mulch (treatment *C*), fixed only ca. 20 kg N ha^{-1} y^{-1}. One explanation may be that the extra available N from the green manure acted as a negative feed-back causing the legume to switch off some of the N_2 fixing process (Schwinning and Parsons, 1996). The FYM treatment did not affect fixation in the same way as mulching, probably because the differences in available soil N were not marked (only about 6% of the FYM-N became available in the seed bed). This may be due to the readily available N component in the well-composted manure being low and the remainder likely to have been mostly recalcitrant organic material. However, increasing soil fertility may develop over time, with the addition of more FYM (supplied again in 2003 as a top-dressing) and the regular input of organic matter from the green-manuring, which may ultimately lead to further reductions in N_2 fixation.

The non-harvested and below-ground plant material (stubble + litter + roots) also contributes to soil organic N and could be important in the longer-term with, on average, about 90 kg N ha^{-1} total N found in all the treatments and with consistently higher amounts (*viz*. an extra 5-12 kg N ha^{-1}) where FYM was supplied.

CONCLUSIONS

Over the short term (< 2 years), well-composted FYM did not inhibit N_2 fixation, but regular additions of green manure reduced N_2 fixation by red clover. The greatest benefit from red clover on stockless organic farms would therefore, appear to be to cut the swards regularly and mulch the herbage onto other areas where soil fertility requires building up.

REFERENCES

Hatch, D.J., Jarvis, S.C., Parkinson, R.J. 1998. Concurrent measurements of net mineralization, nitrification, denitrification and leaching from field incubated soil cores. Biol. Fertil. Soils, 26: 323-330.

Schwinning, S., Parsons A. J. 1996. Analysis of the coexistence mechanisms for grasses and legumes in grazing systems. J. Ecol., 84: 799-813.