Does Chicory inhibit or promote mineralisation?

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Abstract
Chicory is a perennial herb that has the potential to be incorporated into phased farming systems where lucerne is not well adapted. However, little is known about how chicory will influence the availability of N for the following cropping phase. A 16 week incubation study was conducted with chicory and lucerne plants that had been separated into leaves, stems, fine roots and coarse roots. From the beginning of the experiment all plant components of lucerne except for stems underwent net mineralisation. In contrast, the coarse roots were the only plant component for chicory to undertake net mineralisation from the beginning of the experiment. The stems for both chicory and lucerne did not undergo any net mineralisation during the 16 weeks of the study. Accordingly, the stems only released 1.1 % and 1.7 %, respectively, of N applied in plant material during the study. Despite having a C: N ratio approximately a third of the stems, chicory leaves only released 2.5% of N from plant material, which may be due to the delay in net mineralisation during the first 8 weeks of the incubation. Coarse chicory roots released 10.9 % of N from the plant material, although the C: N ratio was 32.3, which was double that of the lucerne roots. Therefore, chicory leaves actually inhibited net mineralisation during the first 8 weeks of the experiment while coarse chicory roots promoted net mineralisation in comparison to lucerne residues.

Key Words
Chicory, lucerne, net mineralisation, net Immobilisation, C: N Ratio

Introduction

Chicory (*Cichorium intybus*) is a perennial herb with the potential for incorporation into farming systems where lucerne (*Medicago sativa*) is not well adapted, such as acidic and waterlogged conditions (Dear and Ewing, 2008; Li *et al.,* 2008). Being a short-term perennial species, chicory could be combined with a highly productive annual legume in phased farming systems allowing farmers to adopt shorter and quicker pasture rotations (2-3 years), in comparison to a lucerne rotation that often requires longer rotations (4-5 years) (Kemp *et al.,* 2002). Chicory's responsiveness to and recovery of applied nitrogen (N) is extremely efficient in comparison to other pasture and crop species currently used in mixed farming systems. The ability of chicory to return N to the system for the following cropping phase will be dependent on how chicory influences mineralisation.

The timing and quantity of N mineralisation from pasture residues is affected by the maturity and species composition of the pasture (Angus *et al.,* 2006; Peoples *et al.,* 2001), timing of pasture removal (Dear *et al*., 2009 In Press), and the biochemical characteristics of the residues (Constantinides and Fownes 1994; Kumar and Goh, 2003; Nourbakhsh and Dick, 2005). The key biochemical factors considered to affect plant residue decomposition are the C: N ratio, lignin, polyphenol and cellulose contents , and the ratio of lignin:N (Jensen *et al.,* 2005), polyphenol: N (Palm and Sanchez, 1991) and polyphenol + lignin: N (Constantinides and Fownes, 1994; Fox *et al.,* 1990).

To date there has been limited investigation into the residue quality and mineralisation of mature chicory plants. An incubation study was conducted to test the hypothesis that chicory roots, stems and leaves would mineralise either at a similar rate or faster than lucerne plants.

Methods

The Soil
Soil was collected from the 0 – 15 cm depth interval of a Red Chromosol soil (Isbell, 1996) derived from granite, located on the Charles Sturt University farm, Wagga Wagga. The area was under a pasture comprising of mixed annual broadleaf and grass species with little to no legume content, which has been the case for the past five years. The moist soil was passed through a 5 mm screen and mixed thoroughly with a cement mixer to obtain a homogenous sample.

Chemical analysis of the soil indicated the soil pH was 5.96 (1:5 1M KCl) and mineral N (NH_4^+, NO_3^- and NO_2^-) was 33.88 mg/kg. The exchangable cations were extracted and concentrations determined by atomic absorption spectroscopy. The ECEC of the soil was 6.73 cmol+/kg, which was given by the sum of exchangeable Ca^{2+}, Al^{3+}, Mg^{2+}, Mn^{2+}, Na^+ and K^+ that were 4.51, 0, 0.64, 0.01, 0.02, 1.56 cmol+/kg, respectively. Field capacity of the soil was 18% gravimetric moisture content. To avoid drying the collected soil, subsamples were taken to determine the gravimetric moisture content. This measurement enabled the total mass of oven dried soil added to jars to be calculated.

The Plants
Established chicory and lucerne plants in their 3rd season were collected from the field in late September. Sampling involved excavating the entire plant including a large proportion of the roots. These plants were then prepared carefully for the various treatments.

Treatments
The chicory and lucerne collected served as plant treatments in addition to a no plant treatment, which was used as the control. Plant shoots were cut from the roots at the soil surface. The shoots were then separated into leaves and stems (primary stems). The roots were carefully washed free of any soil and separated into fine (< 1 mm diameter) and coarse (> 4 mm diameter) root fractions. Each plant species therefore had four separate plant fractions. Following separation each plant fraction was dried individually in the plant dehydrator at 80°C for 48 hours.

Nitrogen mineralisation was determined by an adaptation of the method described by Paul *et al*. (2001). A 1 g portion of the plant fraction was mixed thoroughly with 40 g of oven dry soil and then added to a 375 mL jar. The soil was then watered with deionised water to 90 % field capacity. On a weekly basis jars were opened for approximately 20 minutes to maintain adequate O_2 concentration within the jars. In addition, each week soil samples were re-wet to 90% field capacity weight with a fine spray of deionised water.

There were four replicates incubated for each treatment. Incubation jars were arranged in a completely randomised block design in a constant temperature (20°C) room. There were four blocks with one replicate in each block. All incubation jars were fully covered under aluminium foil to assist with the maintenance of constant temperature and low light intensity.

The duration of the experiment was 16 weeks with a total of 6 sampling times. Sampling of jars occurred immediately after the treatment application, 7 days later, 14 days later, 28 days later, 56 days later and at the completion of the experiment, 112 days after treatment application. At each sampling time incubation jars were distructively sampled by the addition of 200 mL of 1 M KCl for soil pH and mineral N analysis.

Results
The high C: N ratios of 48.1 and 45.2 for the chicory and lucerne stems, respectively, were significantly greater than all other plant fractions (Figure 1). The C: N ratios for coarse (32.3) and fine (37.3) chicory roots were significantly greater than that of the lucerne roots which were 16.1 and 17.2, respectively (Figure 1). The C: N ratio of the chicory leaves (17.5) was statistically the same as the lucerne roots (Figure 1). Whereas, the lucerne leaves had the significantly lowest C: N ratio of 11.2 (Figure 1). The quantity of N applied to jar for the chicory leaves, stems, coarse roots and fine roots was 2.4, 0.9, 1.3 and 1.1 mg/g, respectively. The quantity of N applied to jar for the lucerne leaves, stems, coarse roots and fine roots was 4.1, 1.0, 2.6 and 2.3 mg/g, respectively.

The mineral N for the control treatment remained relatively unchanged throughout the experiment (Figure 2). The control line in this experiment represents a significant boundary that separates net mineralisation and net immobilisation. Mineral N values exceeding the control indicate net mineralisation while values smaller than the control indicate net immobilisation. Therefore, all the plant fractions of lucerne except for stems underwent net mineralisation from the beginning of the experiment (Figure 2). In contrast, the coarse roots were the only plant fraction for chicory to undertake net mineralisation from the beginning of the experiment (Figure 2). Between week 8 and 16 chicory fine roots and leaves underwent net mineralisation (Figure 2). The stems for chicory and lucerne did not undergo any net mineralisation during the 16 weeks of the study (Figure 2).

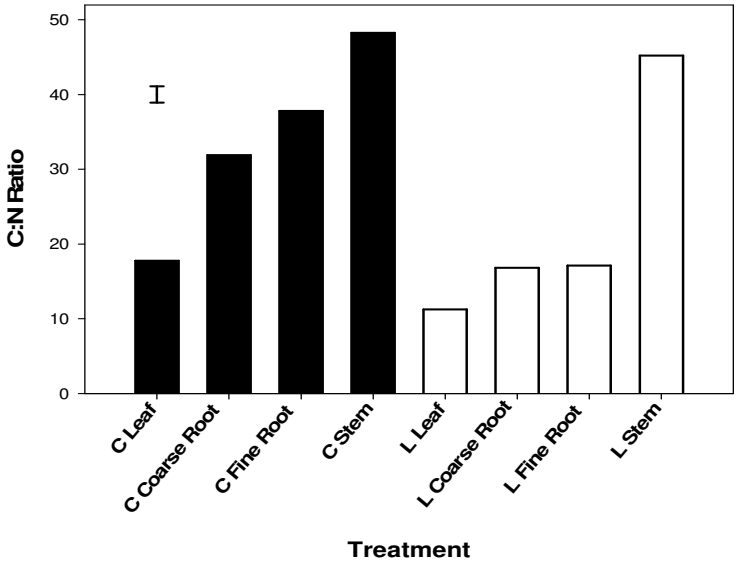

Figure 1. The C:N ratio of the leaves, coarse roots, fine roots and stems from 3 year old chicory (■)and lucerne (□) plants. Bars indicate L.S.D at p< 0.05.

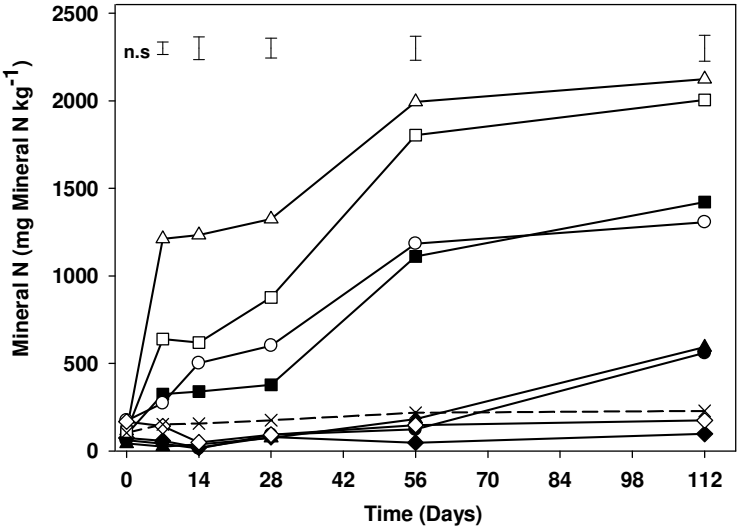

Figure 2. Mineral N concentration (mg/kg) of the soil at the six sampling times for the chicory (■) and lucerne (□) plants. Leaves, stems, coarse roots and fine roots are designated by triangles, diamonds, squares and circles, respectively. The control is designated by a cross and broken line. Bars indicate L.S.D at p< 0.05; n.s, not significant.

To give an indication of the mineralisation rate the proportion of N released from the 1 g of plant material was calculated and presented in Table 1. There was no significant difference in the proportion N released from the lucerne leaves (5.3 %), fine roots (6.5 %) and coarse roots (5.0 %) (Table 1), which all underwent net mineralisation from the beginning of the experiment. The fine roots of chicory also released 5.1% of possible N during the incubation despite only undergoing net mineralisation during the last 8 weeks of the experiment (Table 1). Although the chicory leaves (2.5 %) had a similar C: N ratio as lucerne roots the proportion of N released was not significantly different to the stem treatments, which were significantly lower than all other treatments (Table 1). In contrast, 10.9 % of the N applied in the coarse chicory root treatment was released, which was significantly greater than all other treatments (Table 1).

Table 1. The proportion of N released from the 1 g of plant material added following 16 weeks of incubation. Treatments designated with different letters within the table have released significantly different proportions of N during the incubation period (p< 0.05).

Treatment	Chicory (%)	Lucerne (%)
Leaf	2.5 a	5.3 b
Root (> 1 mm)	5.1 b	6.5 b
Root (< 4 mm)	10.9 c	5.0 b
Stem	1.1 a	1.7 a

Conclusion

Over the 16 weeks of the experiment lucerne behaved as expected with leaves, fine roots and coarse roots all undergoing net mineralisation, while lucerne stems with a high C: N ratio underwent net immobilisation. In contrast, chicory behaved a little differently. Chicory leaves, although having a similar C: N ratio as lucerne roots, underwent net immobilisation during the first 8 weeks of the experiment, which resulted in a lower proportion of N being released from the applied plant material. Coarse chicory roots on the other hand underwent net mineralisation, similar to lucerne roots, despite having nearly double the C: N ratio, which allowed it to release a significantly greater proportion of N from the applied plant material. In conclusion, chicory leaves inhibited net mineralisation during the first 8 weeks of incubation, whereas, coarse chicory roots promoted net mineralisation over the 16 weeks of the experiment in comparison to lucerne.

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