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Calculation of N Mineralization from Six Green Manure Legumes under Field Conditions from Autumn to Spring

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Mean soil temperature values and optimal moisture conditions were incorporated into a kinetic first-order model to describe net nitrogen mineralization from above-ground legume material under field conditions. Calculations showed that red clover, persian clover and egyptian clover would mineralize 1 to 2 kg N ton^{-1} above-ground legume dry matter from autumn to early spring, whereas white clover, black medic and subterranean clover would mineralize between 6 and 13 kg N ton^{-1} of dry matter during the same time period. Late ploughing (December 1) compared to early ploughing (October 15) had a substantial effect on the initial amounts of N released but differences decreased and were small in May. Assuming an above-ground legume biomass of 3 tonnes of dry matter, up to 40 kg N per hectare can be mineralized from autumn to early spring depending on the legume species. The species had a larger influence on the mineralized amounts of N than the location and the time of ploughing. *Key words: Trifolium pratense L., T. repens L., T. resupinatum L., T. alexandrinum L., T. subterraneum L., Medicago lupulina L.*

INTRODUCTION

The aim of this study was to quantify the net nitrogen mineralization from decomposing green manure legumes under various field conditions. The following factors were investigated: 1) species of green manure legume, 2) age of white clover crop, 3) time of ploughing and 4) geographical location/climate.

Kinetic data on net N mineralization from six species of green manure legumes obtained from incubation experiments were reported in the first paper (Marstorp & Kirchmann, 1991). N mineralization kinetics from white clover of different age were published elsewhere (Kirchmann & Bergqvist, 1989). In this study, N mineralization from legume species under autumn–winter–spring field conditions were calculated with the help of mean field temperature values.

MATERIAL AND METHODS

Plant material

Some plant chemical analyses of the six legumes and N mineralization parameters obtained with first-order kinetics at 25°C under optimal moisture conditions are summarized in Tables 1 and 2. The analytical techniques and the estimation of the parameter values were described in the previous paper (Marstorp & Kirchmann, 1991).

Soil climate at two locations

The effect of soil climate on net nitrogen mineralization from legumes was calculated at two different locations in Sweden; Uppsala (59°50′ N, 17°40′ E, altitude 4 m) and Lund (55°40′ N, 13°15′ E, altitude 20 m). Mean soil temperature values for the two localities at day 15 of each month and at 0.2 m soil depth were used (Vedin, 1989), see Table 3. It was assumed that the soil moisture conditions did not limit mineralization during late autumn, winter and early spring and only this time of the year was considered.

Calculations

Net nitrogen mineralization from decomposing legumes in soil followed first-order kinetics as follows:

$$N = N_0(1-e^{-ktf})-I,$$

Table 1. *Plant chemical composition of the six legume species in dry matter*

Species and age (above-ground material)	Organic C ($mg\,g^{-1}$)	Total N ($mg\,g^{-1}$)	C/N
Red clover			
101 days	459	26.1	17.6
White clover			
66 days	422	31.1	13.6
101 days	395	31.0	12.7
137 days	399	29.7	13.4
Black medic			
101 days	429	31.2	13.8
Persian clover			
101 days	461	22.0	20.9
Egyptian clover			
101 days	453	25.2	18.0
Subterranean clover			
101 days	426	30.2	14.1

Table 2. *Parameter values for nitrogen mineralization of six legume species in soil obtained with a first-order function at 25°C*

N_0 = potentially mineralizable crop N fraction, I = initially immobilized or denitrified crop N fraction, k = rate constant, $t_{0.5}$ = time to mineralize half of N_0

Species and age (above ground material)	N_0 ($mg\,g^{-1}$ DM)	I ($mg\,g^{-1}$ DM)	k (day^{-1})	$t_{0.5}$ (days)
Red clover				
101 days	8.26	−1.93	0.017	41
White clover				
66 days	13.09*	0	0.057*	12
101 days	10.47,* 9.92	0	0.056,* 0.045	12
137 days	9.26*	0	0.060*	12
Black medic				
101 days	9.82	0	0.076	9
Persian clover				
101 days	6.96	−2.10	0.024	29
Egyptian clover				
101 days	7.51	−0.95	0.009	77
Subterranean clover				
101 days	8.32	0	0.045	15

* From Kirchmann & Bergqvist (1989).

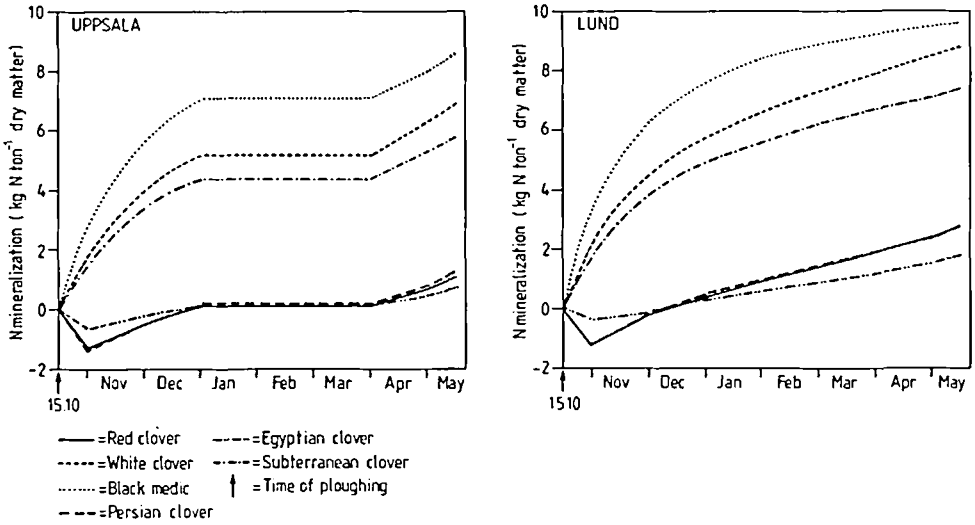

Fig. 1. Calculated net N mineralization from six above-ground legume materials under field conditions.

where N is the amount of nitrogen mineralized, N_0 is the amount of potentially mineralizable legume nitrogen, k is a rate constant, t is time, I is the amount of initially immobilized or denitrified legume nitrogen and f is a temperature correction factor derived from the Q_{10} relationship as follows:

$$f = Q_{10}^{(T-25)/10};\ T > 0°C$$
$$f = 0 \text{ if } T \leq 0;$$

where T is the actual soil temperature and Q_{10} was given the value of 1.8 according to Andrén and Paustian (1987). The initially immobilized or denitrified amount of N described by the constant I was not temperature corrected as our present knowledge is not sufficient

Table 3. *Mean soil temperature (°C) at the 15th of each month over a 10-year period at 0.2 m depth for two localities in Sweden*

	Locality	
Month	Uppsala	Lund
January	−0.4	0.4
February	−0.9	0.4
March	−0.9	1.0
April	1.3	4.9
May	8.0	11.2
June	13.0	16.7
July	15.9	16.7
August	14.6	16.2
September	11.5	14.0
October	7.6	10.3
November	3.1	6.0
December	0.8	1.8

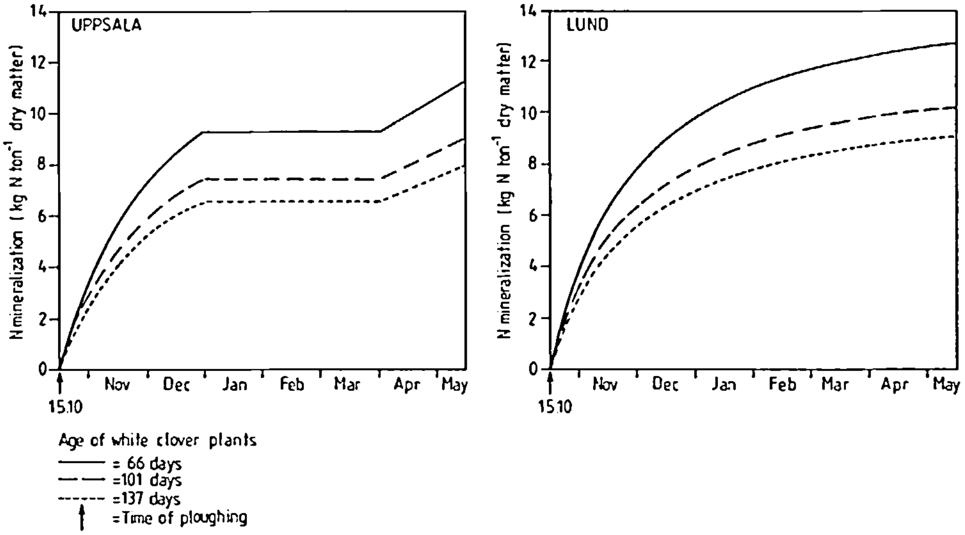

Fig. 2. Calculated net N mineralization from above-ground white clover crops of different age under field conditions.

to identify which process was involved. The neglected correction has a minor, if any, effect on the calculated values. The time required for release of half of the potentially mineralizable N amount of crops was calculated according to the following expression:

$$t_{1/2} = \ln 2/k$$

using *k*-values derived from the first-order model. It was assumed that decomposition of the legume material started after incorporation into the soil.

RESULTS

Fig. 1 shows the net nitrogen mineralization from six different legume species from the time of ploughing in the mid-October until the following May. The nitrogen quantities were expressed in kg N per tonne dry matter. At Uppsala, the net nitrogen mineralization from white clover, black medic and subterranean clover was 7, 9 and 6 kg N per tonne dry matter, respectively. The calculated amounts of net N mineralization from red clover, persian clover and egyptian clover were lower than 2 kg N per tonne dry matter. Legume N mineralization was somewhat higher at Lund than at Uppsala due to differences in soil temperature. The legume species was the main factor causing differences in net N mineralization.

In Fig. 2, the effect of age of one legume species, white clover, on mineralization of legume N is shown. The potentially mineralizable amount of nitrogen (N_0) decreased with plant age (see Table 2). The maximum difference in net N mineralization between young and old white clover plant material was about 4 kg N per hectare and tonne dry matter until May.

In Fig. 3, the effect of ploughing time on N mineralization from red clover and white clover is shown. Net N mineralization from white clover until January was approximately 2–3 times higher after early ploughing (October 15) than after late ploughing (December 1). However, differences decreased during spring and in May a maximum difference of 2 kg N

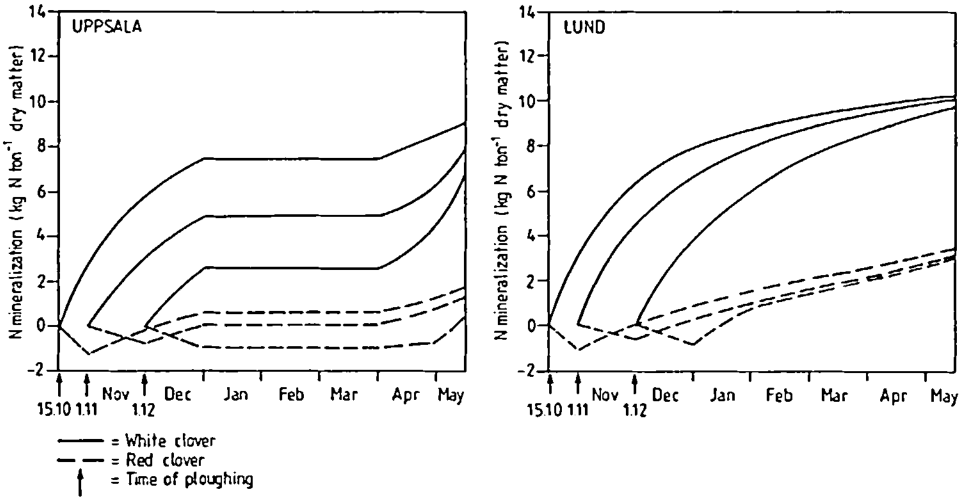

Fig. 3. Calculated net N mineralization from above-ground red and white clover plants after different times of plowing.

per tonne of dry matter was estimated for early and late ploughing, respectively. Net N mineralization from red clover from autumn to spring was rather small. Thus the absolute effect of ploughing time was mariginal for this species.

DISCUSSION

The calculations presented are based on mean temperature values and optimum moisture conditions for decomposition. Thus they are crude estimates. Still, an estimation of this kind shows the importance of the easily influenced factors controlling net N mineralization from legumes during autumn–winter–spring, i.e. choice of species and time of ploughing.

Net N mineralization from red clover, persian clover and egyptian clover was rather low during the period in question. Thus the amounts of legume N that can be leached from these species may be small. On the other hand, white clover, black medic and subterranean clover showed a substantial net N mineralization. If these species are incorporated into soil during early autumn the possibility for leaching of legume N may be greater. Even at later times of ploughing, the amounts of N that can be leached from these species are larger than from red clover, Persian clover and Egyptian clover.

Net N mineralization figures were calculated for one tonne of legume dry matter. Assuming an aboveground legume biomass of 3.0 tonnes of dry matter, amounts of up to 40 kg nitrogen per hectare of legume N can be expected to be mineralized from autumn to early spring, depending on the type of legume used. The species chosen has a larger influence on the mineralized amount of N than the location and the time of ploughing.

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