Nitrogen mineralization *in situ* and in laboratory in Icelandic Andosol

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ABSTRACT

Nitrogen net mineralization was studied in a Brown Andosol at the Korpa experimental station in Southwest Iceland, both *in situ* and in a controlled environment. The soil came from eight barley (*Hordeum vulgare.*) plots in an experiment testing the residual effect of ryegrass (*Lolium multiflorum*) sown with barley in the previous year. The residual effect of ryegrass was not significant. The net mineralization in the field estimated by conversion of net mineralization at constant soil temperature and water tension to conditions in the field was 33 kg ha^{-1} N for the period from early May the to end of September, compared to 31 kg ha^{-1} measured by the soil core in situ method in the field. The results indicate that net mineralization at constant temperature and water content converted to soil conditions can be used instead of the more laborious *in situ* method. The use of laboratory incubation may thus be a useful option in comparison of net mineralization in samples of various soil types under different management methods and crops.

Keywords: Andosol, Iceland, incubation, in situ N mineralization, immobilization, nitrogen

YFIRLIT

Niturlosun í íslenskri móajörð mæld í akri og við staðlaðar aðstæður í rannsóknastofu

Niturlosun í móajörð var mæld í jarðvegskjörnum í tilraun með byggræktun á Korpu og við staðlaðar aðstæður á rannsóknastofu í jarðvegssýnum úr sömu reitum. Niturlosunin var mæld í jarðvegi í átta byggreitum og í jarðvegsýnum úr sömu reitum til að meta eftirverkun af rýgresi, sem sáð var með byggi árið áður. Eftirverkunin var ekki marktæk. Nitur var bundið í móajörðinni samkvæmt mælingum á staðnum í maí, júní og fyrstu viku í júlí, alls 23 kg ha^{-1}, en eftir það til loka september losnaði 31 kg ha^{-1} N. Líklegar ástæður fyrir bindingu N eru ræddar í greininni. Niturlosun við mældan hita og vatn í akurreitunum reiknuð af mælingum við staðlaðar aðstæður var 33 kg ha^{-1} og ber vel saman við 31 kg ha^{-1} mælt á staðnum. Niðurstöður benda til þess að nota megi niturlosun við staðlaðar aðstæður leiðrétta að hitastigi og vatni mældu í jarðvegi á staðnum í stað vinnufrekari mælinga á staðnum sem auk þess krefjast nálægðar við rannsóknastofu. Aðferðin myndi auðvelda samanburð á niturlosun í mismunandi jarðvegsgerðum og ræktun.

INTRODUCTION

Net nitrogen (N) mineralization in volcanic soil (Andosol) in Iceland has been studied both in a controlled environment (Pálmason et al. 1996, Pálmason & Snorrason 2001, Guicharnaud & Björnsson 2004) and by use of the *in situ* soil core method (unpublished results from the Nordic Nitrogen Project NORN, Jansson et. al. 1999). These studies have raised the question as to how mineralization in Brown Andosol (Icelandic: *móajörð;* Arnalds 2004) measured in a controlled environment relates to mineralization measured *in situ* in the field.

Several factors may influence net N mineralization in incubation. Nielsen et al. (2001) reported that severe freezing (-13 °C) did increase net mineralization and N_2O efflux, but mild freezing (-3 °C) had little effect. Net N mineralization is increased by drying the soil, due to autolysis of microorganisms (Mary & Remy 1979, Richter et al. 1982, Nordmeyer & Richter 1985). Disruption of soil structure by drying may also release organic matter from microaggregates and render it available to mineralization by microbes, as discussed by Cabrera & Kissel (1988). They found that overestimation of N mineralized in disturbed soil samples increased with increasing clay/total N ratios in four soil types. Furthermore, net N mineralization in intact soil may be influenced by plant N uptake, as discussed by Schimel & Bennett (2004).

The purpose of the research presented here was to: (1) compare net mineralization in disturbed soil samples (samples kept frozen from sampling until start of incubation in a controlled environment) and net mineralization measured in the field; (2) measure the residual effect of ryegrass sown with barley on net mineralization in soil with a barley crop in the following year; and (3) compare the influence of sampling frequency on the estimate of net mineralization.

MATERIALS AND METHODS

Nitrogen mineralization in situ and in a controlled environment was studied in a Brown Andosol, a common soil type in Iceland. Samples were taken from two treatments out of six in an experiment with pure barley crop and barley with ryegrass as catch crop undersown in 2002 at Korpa in Reykjavík, Southwest Iceland. In 2003 only barley was sown in both treatments to test the residual effect of ryegrass. The soil at Korpa is a freely drained Brown Andosol on a sloping area with soil characteristics as shown in Table 1.

Experimental design and treatments

Soil samples were taken in 2003 from two treatments, each with four replications, in a randomized block experiment with a total of six treatments: (1) pure barley crop (*Hordeum vulgare* L.) as control; (2) mixed crops of Italian ryegrass (*Lolium multiflorum* Lam. *var. italicum*) and barley; and (3) a mixture of Westervoldian ryegrass (*L. multiflorum* Lam. *var. westerwoldicum*) and barley. Two treatments of each crop were fertilized by 60 and 120 kg N ha^{-1} respectively in 2002 and 2003.

The soil was sampled from treatments with (1) barley and (2) a mixed crop of Italian ryegrass and barley in treatments with 60 kg N ha^{-1} fertilization. The ryegrass was sown in 2002 and the residual effect measured in 2003. Barley was sown on 8 May 2003. In 2003 the sampling plots were split into subplots with 60 N kg ha^{-1} and without application of nitrogen. Soils without N application were sampled in four replicated plots from each treatment.

Table 1. Soil characteristics in 0-20 cm soil layer (in fraction < 2 mm) in the Brown Andosol at Korpa in Reykjavík, Southwest Iceland.

	Water content,* C g cm^{-3}	**N-Kjeldahl, % DM**	**Carbon, % DM**	**C/N ratio**	**Mineral content, %**	**Bulk density, g cm^{-3}**
Barley	0.33	0.31	3.7	11.9	92.6	0.948
Barley + ryegrass	0.35	0.38	4.3	11.5	91.4	0.942
		Average and 95% confidence interval of all plots				
Mean of all plots	0.34	0.35	4.0	11.7	92.0	0.95
Lower limit	0.28	0.25	3.0	11.0	90.0	0.78
Upper limit	0.40	0.44	5.0	12.4	94.0	1.11

* Water content at field capacity (10 kPa).

Sampling and extraction

For determination of bulk density soil was sampled from 0-20 cm soil depth with open cylinders 5 cm high and 5 cm in diameter. C, N and water holding capacity at 10 kPa in a soil fraction < 2 mm particle size was determined on samples taken for incubation in the laboratory.

An *in situ* method (Raison et al. 1987, Debosz 1994, Subler et al. 1995) was used to estimate net N mineralization in the field. Steel cylinders, 30 cm high and 4.3 cm in inner diameter, were used for incubation *in situ*. Holes were drilled in the sides of the cylinders to ensure hydraulic continuity, as suggested by Subler et al. (1995). The holes were 3 mm in diameter in four vertical rows, five holes in each row at a soil depth of 4-16 cm. The *in situ* incubation periods lasted for 2 and 4 weeks, starting on 13 May, for the purpose of testing the influence of sampling frequency.

The cylinders were installed, one in each plot, on the first day of each incubation period to a depth of 20 cm and covered with U-tubes excluding leaching by rainfall. For determination of initial inorganic N content (N_{min}), soil samples consisting of four cores, 3 cm in diameter, were taken down to 20 cm within 15-20 cm from each cylinder at the beginning of each incubation period. The soil samples from *in situ* incubations were kept at low temperatures, 2-4 °C, during the time from sampling to extraction, approximately 24 hours. Then, the samples were sieved (2 mm mesh). The two soil fractions from the sieving were weighed for bulk density determinations. Approximately 33 g fresh soil from the < 2 mm fraction was weighed (± 0.01 g) and extracted with 100 ml 1 M KCl, corresponding to a dry soil:extract ratio of 1:4. Subsamples were taken for dry matter determination.

Soil samples for laboratory incubation, at controlled temperature and water potential, were taken in four replicated plots in each treatment at the same time as the in situ incubation started. Soil sampling depth was 0-20 cm. The samples were frozen at -18 °C on the day of sampling. Later samples were thawed overnight and 1-2 kg of soil from each plot was placed in an incubator at 15 °C on the day after thawing. The dry matter of the soil portions and water content at -10 kPa were then measured for sub-samples (Table 1). Seven days after thawing the soil portions from each plot were watered to -10 kPa soil tension (Table 1) and placed again in the incubator at 15°C and further pre-incubated for 22 days. Portions of approximately 50 g soil from 8 experimental plots were weighed (±0.01 g) for incubation, in 3 replications and in sufficient numbers for 8 dates of destructive sampling for ammonium and nitrate analysis. The soil was sieved through a 2 mm sieve before weighing.

Soil corresponding to 12.5 g DM was weighed for extraction of ammonium and nitrate with 50 ml 1M KCl for 1 hour in a rotating extractor. A sub-sample was taken for dry matter determination. Ammonium and nitrate were measured by a distillation method using a Dewarda mixture for reduction of nitrate (Keeney & Nelson 1982).

Calculations and statistics

Net mineralization (N_{min}) in incubated soil *in situ* was calculated by subtracting inorganic N in samples of undisturbed soil (N_{soil}) taken at the beginning of each incubation period from inorganic N in soil cores (N_{core}) after two or four weeks of incubation (Equation 1). The difference in inorganic N in samples from undisturbed soil sampled outside the cores at the end and beginning of the same interval represent net mineralization less uptake and losses from soil (Equation 2).

Net mineralization in the period from day 1 to 14 was estimated by:

$$N_{\min\, day\ 14} = N_{core \cdot day\ 14} - N_{soil \cdot day\ 1} \qquad (1)$$

Furthermore, net mineralization exceeding N uptake in plants and N losses (leaching, denitrification) from soil ($N_{\min - (u+l)}$) was estimated by:

$$N_{\min -(u+l)} = N_{soil \cdot day\ 14} - N_{soil \cdot day\ 1} \qquad (2)$$

Finally, if nitrogen net mineralization in soil cores equals net mineralization in undisturbed soil outside the cores, plant N uptake and N losses from soil in the period from day 1 to day 14, (N_{u+l}) can be calculated as:

$$N_{u+l} = N_{core \cdot day\ 14} - N_{soil \cdot day\ 14} \qquad (3)$$

Net mineralization in the laboratory was measured as nitrogen accumulated from the start of incubation to each sampling date. Potential net mineralization and net mineralization rate were estimated by a single-pool exponential equation of the form:

$$y = Y_{\max}\left(1 - \exp^{-kX}\right) \qquad (4)$$

where y is the net mineralization (negative values of y stand for immobilization), Y_{max} is the asymptotic maximum or potential net mineralization, which equals the pool available for mineralization at the start of incubation, k is the rate constant and X is the time from start in days.

An Arrhenius equation was used to convert net mineralization measured in laboratory incubation at 15 °C and 10 kPa water tension in each incubation period to the actual temperatures in the field:

$$\ln N_{min,i} = \ln N_{min,ref} - \left(\frac{E_a}{R}\right)\left(\frac{1}{T_i} - \frac{1}{T_{ref}}\right) \qquad (5)$$

where $N_{min,i}$ is the rate of net mineralization at the mean temperature measured in the field during the incubation period i, $N_{min,ref}$, is the rate in comparable period in the laboratory incubation, T_{ref}, the reference temperature of 288 °K (15 °C). The gas constant R is known and E_a, the activation energy, can be calculated for a given Q_{10} value.

The adjustment to field conditions was made by use of the Arrhenius equation and Q_{10} valu es in the range of 2-8 and a net mineralization proportional to the ratio of realized water content in soil relative to water content at 10 kPa (Table 2). The range of Q_{10} values used was chosen with reference to research indicating variable Q_{10} values (Stanford et al. 1973, Marion & Black 1987, Andersen & Jensen 2001).

The adjustment for water content in soil (θ) realized in the field in each period was done according to Stanford and Epstein (1974) and Paul et al. (2003):

Table 2. The activation energy (Ea; Joule mole^{-1}) for the three Q_{10} values used in the 5-15 °C temperature range in this study.

Q_{10}	2.0	4.0	8.0
	46 172	92 344	138 516

$$f = \theta / \theta_{10kPa} \qquad (6)$$

where f is a correction factor and $\theta_{10\ kPa}$ is water content at field capacity -10 kPa).

Fitting of exponential and linear functions to the data and statistical analysis (t-tests, analysis of variance) were carried out by use of the Graph Pad Prism, Version 4, Graph Pad Software, San Diego, Cal., USA.

RESULTS

The range of water holding capacity was 0.28-0.40 g cm^{-3}. The range of total carbon (C) in the field experiment was 29-60 mg g^{-1} soil and the range of total N was 2.6-5.4 mg g^{-1} soil (Table 1). Total N and total C in the 0-20 cm soil layer used in the *in situ* incubations and in the laboratory averaged to 4.6 and 54 tons ha^{-1}, respectively

The range of C/N was 10.4-12.6. Total N, water holding capacity and bulk density were closely related to the C content of the soil and the variations followed the experimental blocks and the slope in the experimental area, with soil varying from gravely at the top to soil with a particle size largely below 2 mm at the bottom (Table 1).

Sampling frequency in situ and net mineralization

The effect of sampling frequency was studied by summing net mineralization in two 2-week incubation periods and comparing the result with the corresponding one 4-week incubation that was carried out simultaneously (Figure 1). The effect of sampling frequency was significant (P=0.01, Two-way ANOVA). The interaction between time and sampling frequency was

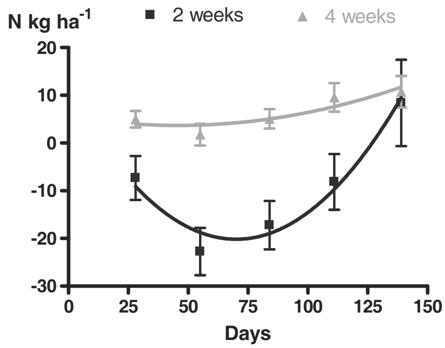

Figure 1. Accumulated net mineralization/immobilization measured *in situ* in 4 week and 2+2 week incubation periods in the 0-20 cm soil layer in the Brown Andosol at Korpa in Reykjavík, Southwest Iceland. The figure shows means of 8 plots and standard error as vertical bars.

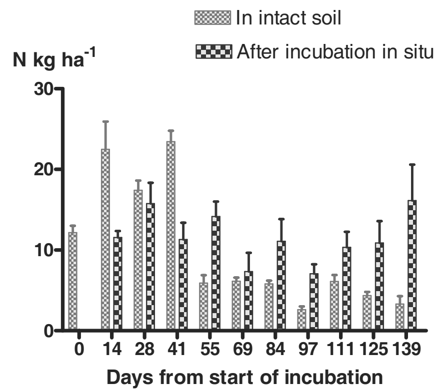

Figure 2. Inorganic N in intact soil outside and inside soil cores after two weeks *in situ* incubation in the 0-20 cm soil layer in the Brown Andosol at Korpa. The figure shows means of 8 plots and standard error as vertical bars.

also significant (P=0.003). The differences in net mineralization between sampling frequencies in each period were only significant in the last period (Table 3). The linear rates of net mineralization from day 55 were 0.37 kg N ha^{-1} day^{-1} (0.16 to 0.57, 95% confidence interval) and 0.11 kg N ha^{-1} day^{-1} (0.03 to 0.20, 95% confidence interval) for the 2 and 4 week periods, respectively.

Inorganic N in intact soil

The level of mineral N in intact soil in the experimental plots was 11-13 kg ha^{-1} in the 0-20 cm layer of intact soil in the field at the first sampling in spring shortly after sowing, increasing into late June and reaching 23-24 kg ha^{-1}, decreasing in the next two weeks to 5-7 kg ha^{-1} and staying at a low level until the end of September (Figure 2).

Net mineralization in controlled environment and in situ

The results from the incubation at standard temperature and water content are shown in Table 4. No net mineralization occurred during the first week of incubation and it was not significant in the second week. The exponential equations for net mineralization are therefore based on data from days 14-139. The potential net mineralization and the rate constants were not significantly different for the two data sets, i.e. the residual effect of ryegrass sown with barley in the previous year was not significant.

The residual effect of ryegrass sown in the previous year with barley was also measured *in situ* in the soil with a barley crop. There, the residual effect was not significant for the first 55 days of immobilization (Two way ANOVA, P= 0.30) nor in the fol-

Table 3. Differences in net mineralization in the field between 2+2 weeks and 4 week incubation periods, kg ha^{-1} period^{-1}. Post-ANOVA pairwise differences were tested by Bonferroni tests. Ns stands for not significant, * stands for P<0.05.

Days	2+2 weeks, kg ha^{-1} period^{-1}	4 weeks, kg ha^{-1} period^{-1}	Difference, kg ha^{-1} period^{-1}	t-value	
28	-7.3	5.0	12.3	2.86	ns
55	-15.4	-3.2	12.2	2.82	ns
84	5.5	3.3	-2.2	0.51	ns
111	9.1	4.5	-4.6	1.07	ns
139	16.6	1.2	-15.4	3.57	*

Table 4. Best fit of Equation 4 for accumulated net mineralization (kg N ha^{-1}) at 15°C and 10 kPa water tension in the 0-20 cm soil layer in Brown Andosol at Korpa. Ymax is the potential net nitrogen mineralization and k the rate constant and SE is standard error. Soil sampled in spring 2003.

Treatment	Y_{max}	SE	k	SE	R^2
Control (barley)	63.2	3.0	0.0312	0.0053	0.75
Barley and ryegrass	67.9	4.6	0.0255	0.0055	0.71
All data (8 plots)	65.4	2.6	0.0283	0.0038	0.72

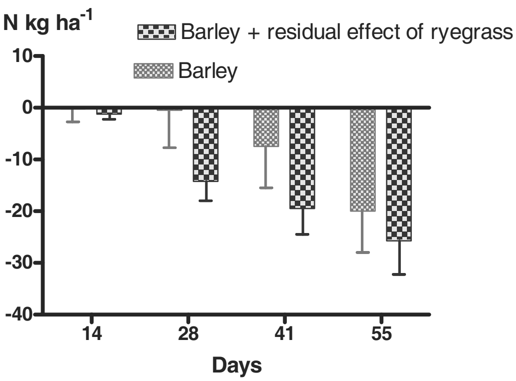

Figure 3. Accumulated nitrogen immobilization during the first 55 days of *in situ* incubation in barley (control) and in barley with residual effect of ryegrass sown in previous year at Korpa.

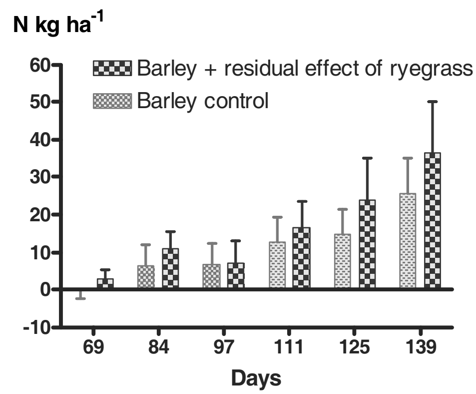

Figure 4. Accumulated nitrogen net mineralization from day 55 to 139 of *in situ* incubation in barley (control) and in barley with residual effect of ryegrass sown in previous year at Korpa.

Table 5. Average daily *in situ* net immobilization/mineralization (negative/positive; kg N ha^{-1} day^{-1}) in the 0-20 cm soil layer in the Brown Andosol at Korpa. Significant deviations from zero (one sample t-test) are indicated by bold format.

Days	Mean	SE	t-value	P-value
0-14	-0.015	0.089	0.17	0.87
14-28	-0.481	0.266	1.81	0.11
28-41	-0.470	0.167	2.82	**0.03**
41-55	-0.662	0.141	4.71	**0.002**
55-69	0.102	0.119	0.86	0.42
69-84	0.326	0.169	1.93	**0.09**
84-97	0.104	0.102	1.01	0.34
97-111	0.551	0.139	3.98	**0.005**
111-125	0.341	0.156	2.19	**0.06**
125-139	0.841	0.324	2.60	**0.04**
Plot average, min and max during two longer periods				
Days		0-55		69-139
Average		-0.41		0.38
Min		-1.45		-0.47
Max		0.96		2.33

lowing period of net mineralization (P= 0.56; Figures 3 and 4).

Rates of net immobilization in the field increased from the start of incubation in situ on 13 May and reached a highly significant daily rate of 0.66 kg ha^{-1} in the period from 23 June to 7 July (day 55) (Table 5). From day 55 net mineralization increased and reached a maximum of 0.84 kg ha^{-1} in the period from 15 September to 29 September (day 139).

In the field the net immobilization accumulated to -23 ± 5 kg N ha^{-1} in the first week of July (day 55), after which the net mineralization reached 31 ± 8 kg ha^{-1} to the end of September (day 139) (Figure 5 B).

Table 6. N uptake and losses (estimated by Equation 3; kg N ha^{-1}) in the 0-20 cm soil layer in the Brown Andosol at Korpa. Significant deviations from zero (one sample t-test) are indicated by bold format.

Days	Mean	SE	t-value	P-value
0-14	-10.9	3.82	2.86	**0.02**
14-28	-1.6	2.60	0.63	0.54
28-41	-12.1	2.56	4.73	**0.002**
41-55	8.3	1.73	4.79	**0.002**
55-69	1.2	2.21	0.54	0.61
69-84	4.5	2.76	1.65	0.14
84-97	4.4	1.42	3.13	**0.02**
97-111	4.2	1.41	3.00	**0.02**
111-125	6.5	2.56	2.54	**0.04**
125-139	12.8	4.05	3.16	**0.02**

Equation (3) for N uptake and losses resulted in significant negative estimates in the first 41 days, amounting to -25 kg ha^{-1} (Table 6). The sum of N uptake and losses from day 41 to 139 was 42 kg ha^{-1}.

Conversion of net nitrogen mineralization in controlled environment to field conditions

Net mineralization converted to field conditions using the Arrhenius equation and Q_{10} of 2.0 resulted in potential net mineralization 33.7 ± 1.3 kg N ha^{-1} comparable to 31.1 ± 7.9 kg ha^{-1} maximal *in situ* net mineralization accumulated from day 55 to 139 (Table 7, Figure 5).

Potential net mineralization, carbon and water contents in soil

Potential net mineralization (Y_{max}) kg ha^{-1} in a controlled environment was related to actual water content at 10 kPa (WC) in g cm^{-3} as shown below (Figure 6):

$$Y_{max} = 24.4 + 118.9 \times WC \qquad (7)$$

The equation accounted for 94% of the variation in Y_{max}. The standard error for intercept was 4.4 and 12.6 for the slope (g H_2O cm^{-3} soil). The *WC* varied between experimental

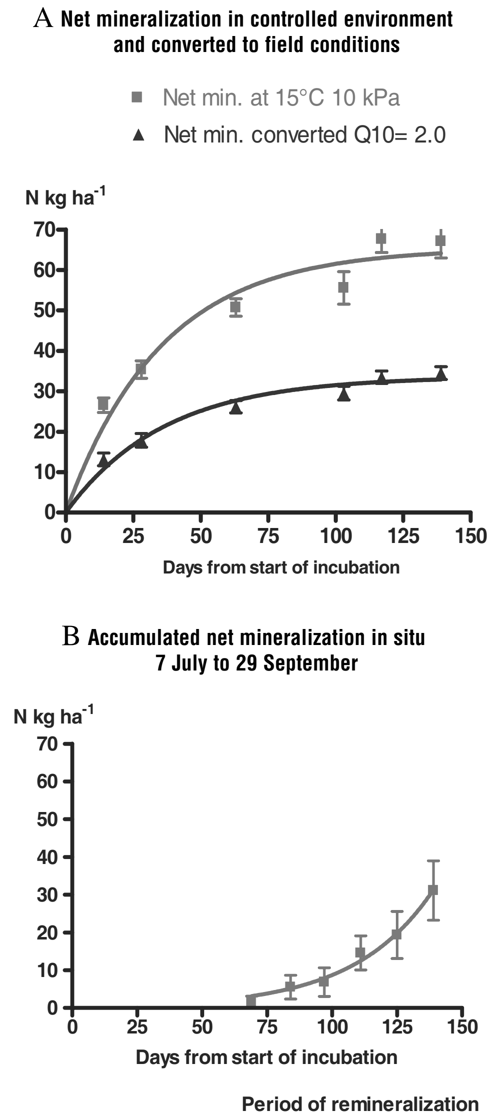

Figure 5. Net mineralization in soil of eight experimental plots on the Brown Andosol at Korpa.
A) Incubation at standardized conditions in the laboratory converted to field conditions with Equations 5 and 6 and parameter values from Tables 4 and 7.
B) Net mineralization measured *in situ* from day 55 after period of immobilization.

Table 7. Potential net mineralization (Y_{max}) and rate constants in a one pool exponential equation after conversion of net mineralization measured in the laboratory at 15 °C and soil water tension of 10 kPa to field conditions by use of three Q_{10} values. Values are averages ± standard error, n = 46.

Q_{10} values	2.0	4.0	8.0
Y_{max}	33.7 ±1.34	25.0 ±0.71	17.2 ±0.50
K	0.0275 ±0.0037	0.0261 ±0.0024	0.0244 ±0.0022
	Goodness of Fit		
R^2	0.74	0.87	0.89

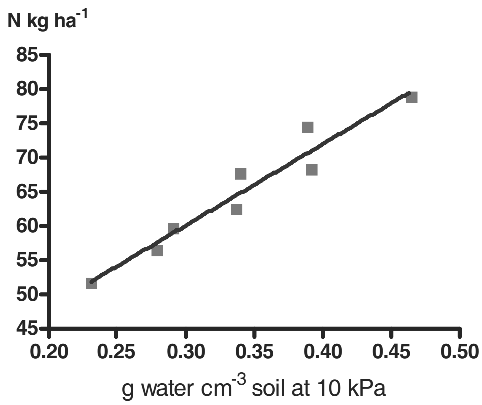

Figure 6. Potential net mineralization (Y_{max}) in soil in relation to water content in soil at field capacity. The data came from 8 field plots with variable water holding capacity and C and N content. Y_{max} was estimated after laboratory incubation at 15 °C and 10 kPa water tension by Equation 4.

plots, as was expected from the variation in organic matter and total C in the soil:

$$WC = 0.0424+0.011\times[C] \quad (8)$$

where [C] is the total carbon content in mg C cm^{-3} soil. The equation accounted for 93% of variation in the soil water at 10 kPa. The standard error for intercept was 0.033 and 0.001 for the slope.

DISCUSSION

The residual effect of ryegrass undersown as a catch crop with barley on net mineralization was not significant, although there were some positive trends observed in the second year (11 kg N ha^{-1}; Figure 4). This is in line with reported results from experiments with ryegrass as catch crop for spring cereals. In Denmark, where perennial ryegrass was used as catch crop in spring barley for three years, the ryegrass effectively reduced nitrate leaching but the retained N did not have any beneficial effect on spring barley yield (Thomsen 2005). As reviewed by Thomsen (2005) “Short-term experiments with ryegrass as catch crop generally show low or even negative effect on the following crop. However, after long term use of catch crops, the N content in soil is raised and thus also the amount of N mineralized from soil.“ Annual undersowing of westerwold ryegrass in spring cereals for six successive seasons on two sites in Finland decreased cereal grain yields and did not affect soil mineral N in the spring (Kankanen et al. 2001)

Rates of net immobilization and net mineralization were reduced in the four week incubation period compared to the 2 week periods. Hatch et al. (1998) pointed out that in the various *in situ* methods the “samples are often isolated during incubation from normal fluctuations in soil moisture and ambient soil temperature, although the effect of the latter is generally not great.“ Hatch et al. (1998) thus used 4-5 day periods of incubation in situ in order to minimize differences in soil moisture. For the same reason Gill et al. (1995) used incubation periods of 7 days. On two dates of soil sampling the water content in intact soil samples was not significantly different from the water content in soil after two or four weeks of incubation. The results presented and discussed in this paper are based on the two week incubation periods as the shorter periods may better represent the environmental conditions of the intact soil in the experimental plots, as discussed by the above cited authors.

The adjustment for temperature was in the range 5-15 °C and was made with three Q_{10} values (2.0, 4.0 and 8.0), each separately used for the whole range of actual temperatures 5-15 °C. These Q_{10} values were chosen with reference to reported values from *in situ* measurements in field experimental plots. According to Marion & Black (1987) such Q_{10} values could vary between 1.7 and 3.0 (5 references). Higher values of Q_{10} for gross mineralization have been reported for low temperature ranges by Andersen & Jensen (2001), i.e. Q_{10} = 4.0 and 9.9 for days 1-9 and 12-37, respectively, in the temperature range 3-9 °C. At slightly higher temperatures, 9-15 °C, they found Q_{10} values of 1.4 and 1.9 for days 1-9 and 12-37, respectively. However, in an earlier field study, Stanford et al. (1973) found similar Q_{10} values of 1.9, 1.8 and 1.8 for the temperature ranges 5-15, 15-25 and 25-35°C, respectively.

In the first periods of incubation *in situ* net N immobilization was measured, but from day 55 (7 July) the field method showed a net mineralization comparable to that measured in the controlled environment after conversion to field conditions. Negative estimates of N uptake and losses calculated from the *in situ* incubation (Equation 3) indicated an overestimation of immobilization in the enclosed soil cores as compared to soil outside the cores (Table 3). Several reasons may account for the overestimation of net immobilization, and the subsequent negative estimate of N uptake and losses (Table 5 and 6): (1) Denitrification may have been higher in the isolated soil cores, as has been suggested in studies by Jensen et al. (1996), Abril et al. (2001) and Vor & Brumme (2002); (2) Release of carbon compounds from damaged fine roots may have lead to increased immobilization (Debosz & Winter 1989, Rees 1989); and (3) Exclusion of plant uptake in the *in situ* method may have led to immobilization of plant available N, underestimating net mineralization or overestimating net immobilization (Schimel & Bennet 2004).

The results of this study indicate that potential net mineralization in an Andosol soil determined in a controlled environment can, after conversion to field conditions, yield net mineralization data similar to those measured *in situ*. Further incubation studies of various soils of Andosol type in Iceland should be done to increase our understanding of the soil nitrogen cycle. Such studies may even yield valuable information for future fertilizer recommendations with respect to environmentally sound use of nitrogen fertilizers.

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