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An easy pot incubation method for measuring nitrogen mineralization from easily decomposable organic material under well defined conditions

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Abstract

A pot incubation method for measuring mineralization dynamics from fresh plant material was tested. The aim was to develop a method which under well-defined conditions could produce mineralization data suited for estimating model input parameters for nitrogen prediction models. The results showed that the water tension of the soil could be controlled easily and precisely by diffusion through porous ceramic cups, and that nitrogen mineralization or immobilization could be measured already after 15 days at 15°C. The results showed that for the incubated catch crop residues carbon, nitrogen and nitrate-N contents were the most important factors determining mineralization. No significant effects ould be ascribed to other parameters measured.

Introduction

When catch crops are grown to reduce the losses of nitrogen from agricultural soils to the environment they will increase the supply of nitrogen from the soil to the succeeding crops. When catch crops are grown under high fertility conditions, they may supply substantial amounts of nitrogen for the first succeeding crop. This effect has been found strongly dependent on the choice of catch crops (Elers and Hartmann, 1987; Sorensen and Thorup-Kristensen, 1993; Thorup-Kristensen, 1994). If the environmental effect of catch crops is to be fully exploited, this increased supply should lead to a reduced input of fertilizer nitrogen (e.g. Thorup-Kristensen, 1993).

In order to reduce the nitrogen fertilization of the succeeding crops significantly, the residual effect of the catch crops ought not only to be large but also predictable. Several attempts have been made to predict the nitrogen turnover in agricultural soils through computer models (Hansen et al., 1991; Paustian et al., 1992; Verberne et al., 1990), and to try to make these models simulate the nitrogen effects of catch crops would be an obvious way trying to make their effect more predictable.

The parameters for the turnover of organic matter in the nitrogen prediction models are generally based on long term measurements of nitrogen turnover, and the organic materials investigated have often been the soil organic matter itself, farmyard manure, or straw. All of these materials are much more resistant to microbial decay than fresh green plant material from catch crops. Data for the nitrogen release after incorporation of easily decomposable plant material are needed as input to the models if they are to be used to simulate the effects of catch crops.

The information needed to make the models simulate mineralization from organic materials are parameters for assigning the carbon and nitrogen content of the plant material to two or three subpools (depending on the model) and the decay rates of each of these pools. The difterent pools have often been assumed to cover defined chemical fractions e.g. water soluble contents, structural components, and lignin. If this fractionation could be made by chemical analysis it would ease the use of the models.

In experiments where nitrogen mineralization from different plant materials has been compared, it has been found that the C/N ratio was the most important

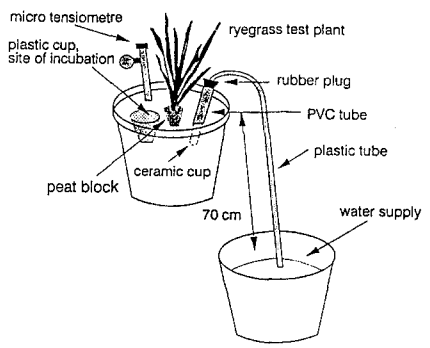

Fig. 1. The experimental setup.

parameter determining the results (Frankenberger and Abdelmagid, 1985; Marstorp and Kirchmann, 1991). This suggests that, at least when comparing fresh green plant materials, chemical analysis dividing the organic matter into the different subpools is not likely to improve the results. Other results, though, have indicated that improvement could be achieved by further analysis. Andren (1987) found that apart from C/N ratio, the contents of water soluble components in the plant material was an important parameter, and Fox et al.(1990) found that the content of lignin and polyphenols were important factors.

Methods for measuring nitrogen release from organic materials are based on incubation followed either by soil analysis to determine soil inorganic nitrogen content, or by analysis nitrogen uptake by test plants. Methods based on soil analysis have the disadvantage that the nitrogen availability for the microorganisms will vary strongly between treatments. Bremer et al. (1991) found that variable soil nitrogen availability will influence mineralization. Methods using test plants have often had the disadvantages that precise control of soil temperature and humidity are difficult and laborious to achieve, and that measurements shortly after incubation are difficult to obtain. This last problem led Fox et al. (1990) to combine the methods and use soil analysis for the first measurement and test plants for the subsequent measurements.

The objective of the present experiment was to develop and test a pot incubation method, where data could be obtained under well-defined conditions, to make them suited for estimating input parameters to the nitrogen prediction model DAISY (Hansen et al., 1991). A further objective was to investigate the relation between mineralization and the chemical composition of the incubated plant material.

Materials and methods

Nitrogen mineralisation was measured by a pot incubation method. Italian ryegrass was used as test plant, and the set up of the experiment had four main objectives:

1 To be able to make the first measurement shortly after incorporation,
2 To keep soil temperature constant,
3 To keep soil water tension constant, and
4 To be able to measure a potential immobilization.

The incubations were made in pots containing 1700 g of air dry field soil (2% organic matter, 11% clay, 14% silt, and 73% sand). Approximately two weeks before the incubations were made, ryegrass plants were transplanted into the pots. The ryegrass plants had been established and pregrown in peat blocks (c. 12 cm^3 of peat). To make space for the subsequent incubation a plastic cup with a volume of 240 cm^3 was placed in the pot too (Fig.1). Artificial light was given to the plants during the winter to ensure vigorous growth.

Before incubation the plant materials were chopped into pieces of 2-3 cm length and mixed with 150 g of soil. Incubations were then made by removing the plastic cups and placing the mixtures in the holes left. Subsequently the mixture was covered with 75 g of field soil. At the time of incubation ryegrass roots were present around the holes in which the incubation material was placed.

The setup which made it possible to incubate plant materials in pots where plants were already growing was made to be able to make the first measurement shortly after incubation.

To keep the temperature constant at 15°C, the pots were placed in an insulated box in a greenhouse, where both cooling and heating were possible. A layer of Perlite was put on top of the soil in the pots, to reduce interception of sunlight and evaporation from the soil surface. Temperature was recorded in two of the pots every 30 minutes throughout the experiments.

To keep the water tension constant a ceramic cup was inserted in each pot. Through a plastic tube the ceramic cups were connected to a water supply placed 70 cm below the pots (Fig.1). The water tension inside the ceramic cups was thus constant at -7.0 kPa, and by water movement through the ceramic material it was in equilibrium with the soil water. The ceramic cups were of the type normally used for tensiometers, but the ceramic material was specified as a "high flow" type. The cups were cylindrical, 80 mm long and, 22 mm in external diameter. At the top of the ceramic cups a 10 cm long piece of PVC tube with an inner diameter

of 22 mm was fixed, into which the plastic tube could be plugged.

After the ceramic cups had been used for two cycles of experiment, i.e. been in the soil for about a year, their resistance to water movement was measured. For this measurement the ceramic cups with their tubes were made to connect two containers with water placed at different heights, the lower placed on a weight to measure throughflow. The water flow was measured three times with each of three ceramic cups, and their resistance to water flow (W) calculated as:

$$W(s/cm^2) = \text{time}(s) \times \text{height}(cm)/\text{throughflow}(cm^3) \quad (1)$$

To be able to measure a potential immobilization it was necessary to secure that nitrogen was present for potential immobilization. Therefore 47 mg of urea-N was added to all the incubations and the control treatment was 150 g of soil mixed with 47 mg urea-N.

Production of experimental material

Plant material for the incubations was sampled from two field trials with catch crops. Material of the species winter rye (*Secale cereale*, var 'multicaule'), Italian ryegrass (*Lolium multiflorum*), phacelia (*Phacelia tenacetifolia*), hairy vetch (*Vicia villosa*), oil radish (*Raphanus sativus*), white mustard (*Sinapis alba*), oats (*Avena sativa*) and narrow leafed lupin (*lupinus angustifolia*) were used for the incubations (Table 1). For details of the field trial see Thorup-Kristensen (1994). The plant material was analysed for its content of nitrogen, nitrate nitrogen, carbon, and lignin (Van Soest, 1963). Some of the samples were further analysed for tannin (AOAC, 1965), and for *in-vitro* digestibility of their dry matter and nitrogen (Tilley and Terry, 1963). The *in vitro* digestibility analysis was used as it is an analysis of microbial digestibility of organic material in the rumen of ruminant animals. The analyses of tannins gave values close to 1% for all plant materials and are not shown, the other results of chemical analysis are given in Table 1.

Experiment 1

The experiment was made to analyse the suitability of the system for estimating mineralization after only 15 days, and possibly within even shorter periods. Four plant materials and a control were incubated (Table 1) in four replicates. The incubations were made on 29 September and test plants were cut at either 3, 8 or 15 days after incubation. At each date both shoots and roots+stubble were analysed for dry matter and nitrogen content.

Experiment 2

The experiment was made as a complete block design with 12 treatments and 6 replicates. Apart from the plant materials (Table 1) incubations with phacelia plus 3 g of sucrose were included. Incubations were made on 16 November 1990 with fresh plant material cut one day earlier. It was attempted to add plant material with a nitrogen content of about 200 mg N to each pot, but as the chemical composition was not known until later, the actually incubated amounts were within the range of 114 to 243 mg nitrogen per pot. The test plants were cut at 15, 36, 69, 105, and 155 days after incubation of the plant materials, and analysed for nitrogen uptake.

Experiment 3

The experiment was performed with 7 plant materials (Table 1), incubations containing 50, 100 or 200 mg N/pot of each, and 3 replicates, (6 replicates of the control). Vetch, oats and lupin were only incubated at 100 and 200 mg N/pot. Except for ryegrass and phacelia, the plant materials incubated were taken from the same samples as those used in experiment 2, though they had now been dried for 24 hours at 60 °C. The incubations vere made on 20 September and the test plants were cut after 15, 36, 73, 120, and 188 ays. After the last cut the roots were cleared of soil, and roots and stubble analysed for nitrogen content.

Results

During the winter the temperature was very precisely controlled, with temperatures within 15.0 ±0.5 °C. In the beginning of experiment 3 and in the end of experiment 2 and 3 (i.e. in the autumn and in the spring) the outdoor temperatures were higher, and solar irradiation was higher, and temperature control became less successful. Some days the maximum soil mperatures rose to 18-20 °C, but no day had average soil temperatures above 16.5 °C, and no period (between two cuts) had average soil temperatures above 15.6 °C.

Table 1. Amount and composition of incubated plant materials in the three experiments. Inv. N and inv. DM are the percentage of nitrogen and dry matter which were solubilized by the invitro digestability method

Species	Inc. N	N	NO_3-N	C	Lignin	C/N	Inv. N	Inv DM
	mg/pot	% of dry matter				ratio	% of total	
Experiment 1								
Oats	143	2.9	0.4	38	5	13.2	.	.
Phacelia	188	3.8	1.1	35	7	9.1	.	.
Ryegrass	168	3.4	0.3	38	3	11.2	.	.
Vetch	124	5.0	0.1	42	13	8.5	.	.
Experiment 2								
Lupin	207	3.5	0.0	44	4	12.6	85	47
Mustard	163	2.7	0.4	40	6	14.8	80	36
Oats	243	2.5	0.2	43	3	17.0	76	58
Phacelia	179	2.1	0.3	34	10	16.0	62	24
Ryegrass	114	2.6	0.0	41	2	15.9	84	54
Radish	194	2.6	0.1	40	3	15.2	89	53
Vetch	217	4.7	0.1	43	4	9.2	82	49
Rye	128	3.4	0.0	41	3	12.0	81	43
Phac. + sugar	179	.	.	.	.	23.4	.	
Experiment 3								
Phacelia	50/100/200	2.7	0.3	34	9	12.4	.	.
Ryegrass	50/100/200	2.8	0.1	41	1	14.8	.	.
Mustard	50/100/200	Same materials as in experiment 2						
Radish	50/100/200	do.						
Lupin	100/200	do.						
Oats	100/200	do.						
Vetch	100/200	do.						

Water potential control

The soil water tension was checked with small tensiometers placed opposite the ceramic cups in some pots. The readings of the tensiometers were very constant during most of the experiments, though small increases in water tension were sometimes observed when the plants were big shortly before a cut. The resistance (W) of the ceramic cups to water flow was measured as between 4000 and 5000 s cm^{-2} for all of the tested cups. Under Danish conditions full grown green house crops have a maximum evapotranspiration of 7-8 l m^{-2} d^{-1} (J.Willumsen, unpublished). In the present experiment there were 25 pots m^{-2}, and at maximum evapotranspiration the water loss would have been 320 ml pot^{-1} day^{-1}. If this evapotranspiration was concentrated within 12 hours of the day, each ceramic cup had to deliver a maximum of 27 ml $hour^{-1}$. At a resistance of 5000 s cm^{-2} the potential difference across the ceramic cup has to be 3.7 kPa to drive this water flow. With a potential of -7.0 kPa inside the ceramic cup, a maximum potential of -10.7 kPa should be found on the outside of the cup wall when the evapotranspiration is at its highest level.

Mineralization measurements

Early measurement of mineralization

During the first 15 days the effect of adding plant material on nitrogen uptake by the ryegrass was found to be as high as 31 mg N/pot 21 (Table 2), and reduced uptakes, supposedly due to immobilization, of up to 17 mg per pot were found. These maximum values occurred in experiment 3 but they were not very different from the results found in experiment 2. The varia-

Table 2. Early nitrogen uptake in shoots of ryegrass test plants by cuts 3, 8, or 15 days after incubation (exp. 1) or 15 days after incubation (exps. 2 and 3)

	Experiment 1			Experiment 2	Experiment 3		
	day 3	day 8	day 15		50 mg N	100 mg N	200 mg N
Control	14	28	48	43	50	50	50
Lupin	.	.	.	45	.	53	62
Mustard	.	.	.	52	50	54	52
Oats	.	.	48	44	.	53	61
Phacelia	18	27	55	54	49	49	71
Ryegrass	15	30	50	36	40	33	36
Radish	.	.	.	44	46	53	49
Vetch	.	.	57	65	.	67	81
Rye	.	.	.	44	.	.	.
Phac.+ sugar	.	.	.	36	.	.	.
$LSD_{0.05}$	4	9	11	11	14	12	14

$LSD_{0.05}$ was calculated by the GLM procedure (SAS Institute, 1998).

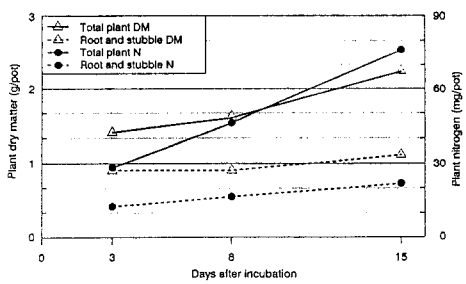

Fig. 2. Dry matter and nitrogen contents in ryegrass test plants at 3, 8, and 15 days after incubations. Experiment 1, average of all treatments.

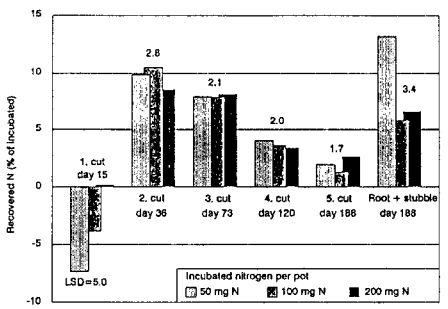

Fig. 3. Effect of amount of incubated N on nitrogen recovery in experiment 2. The data shown are average of the plant materials where all three levels were performed. $LSD_{0.05}$ was calculated by the GLM procedure (SAS Institute, 1988).

tions in experiment 1 were smaller, increased uptakes at the first cut of only 1 to 10 mg N/pot were found.

The results of the experiment 1 showed that most of the nitrogen accumulation in the ryegrass plants during the first period occurred in the shoots (Fig. 2). Between 3 and 15 days after incubation only 17% of the increase occurred in the roots and stubble. During this experiment no difference in plant dry matter production occurred due to the incubation of different plant materials, a result that is in contrast with the results in experiments 2 and 3.

Measurements of immobilization

Significantly reduced nitrogen uptake at the first measurement, presumably due to immobilization, was found after incubating Italian ryegrass (reductions of 7 to 17 mg N/pot, Table 2) in experiments 2 and 3. The effects were equivalent to 5 to 10% of the incubated nitrogen. In experiment 2 also the phacelia+sugar incubation led to a reduced nitrogen uptake of 6 mg N/pot less than the control and 17 mg N/pot less than where phacelia was incubated without sugar.

Effect of amount and composition of incubated material

The effect of the amount of plant material added was investigated in experiment 3, and no difference was found in relative mineralization between incubations containing 100 mg N/pot and 200 mg N/pot (Fig.3). Incubations containing 50 mg N/pot led to lower estimates of mineralization at the first cut, and to a higher

Table 3. Regression equations for the relationship between nitrogen recovery in ryegrass testplants (N_{rec}) and incubated amounts of organic nitrogen (org-N), carbon (C) and nitrate nitrogen (NO_3-N). All values are in mg/pot. The regressions were calculated by the SAS GLM procedure (SAS Institute, 1988)

Experiment 2					
Cut 1[a]:	N_{rec} = -11 +	org-N × 0.28**	- C × 0.016**	+ NO_3-N × 0.87*,	R^2=0.93
Cut 2[a]:	N_{rec} = 10 +	org-N × 0.14**	- C × 0.005*		R^2=0.78
Cut 3 to 5[b]:	N_{rec} = 7 +	org-N × 0.24 **	- C × 0.003		R^2=0.83
Cut 1 to 5[b]:	N_{rec} = 3 +	org-N × 0.70 **	- C × 0.027**	+ NO_3-N × 1.16*,	R^2=0.93
Experiment 3					
Cut 1[a]:	N_{rec} = -6 +	org-N × 0.34* * *	- C × 0.021*	+ NO_3 -N × 0.48,	R^2=0.51
Cut 2[a]:	N_{rec} = 3 +	org-N × 0.19* * *	- C × 0.007* * *		R^2=0.89
Cut 3 to 5[b]:	N_{rec} = -1 +	org-N × 0.17* * *	- C × 0.001		R^2=0.92
Cut 1 to 5[b]:	N_{rec} = -4 +	org-N × 0.71* * *	- C × 0.030* * *	+ NO_3- N × 0.59(*),	R^2=0.87
Total[c]:	N_{rec} = -1 +	org-N × 0.78* * *	- C × 0.032* * *	+ NO_3- N × 0.76*,	R^2=0.89

[a]Nitrogen recovery in cut; [b]Cumulated nitrogen recovery in cuts; [c]Cumulated nitrogen recovery in cut 1 to 5 and roots and stubble after cut 5; *, ** and * * * means significant at the 0.1, 0.05, 0.01 and 0.001 levels respectively.

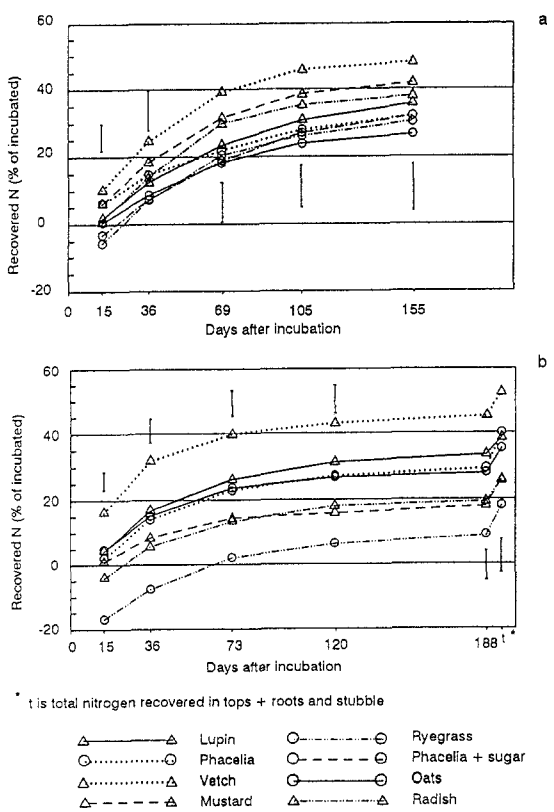

Fig. 4. Recovery of incubated nitrogen in **a**: experiment 2, and **b**: experiment 3. Error bars indicate $LSD_{0.05}$ as calculated by the GLM procedure (SAS Institute, 1988).

fraction of the recovered nitrogen to be found in the roots and stubble at the end of the experiment.

The only chemical factors which were found to be significantly correlated to the amount of mineralized nitrogen were the incubated amounts of nitrate-N, organic-N and carbon with the plant materials. No correlations were found between mineralization and content of lignin, total polyphenols or *in vitro* digestible carbon or nitrogen. Measured mineralization within the first 15 days indicated that practically all nitrate-N was assimilated within this period in experiment 2 where as in experiment 3 the effect of nitrate-N and organic-N was almost identical (Table 3). Nitrogen mineralization was negatively correlated to carbon content, a relation that was strongest at the first measurement and became less pronounced at the later cuts (Table 3).

As the plant materials contained variable amounts of nitrate, estimating a C/N ratio above which immobilization occurred is complicated; the plant nitrate is in mineral form at the time of incubation. Thus addition of the plant material may increase nitrogen uptake in the test plants while at the same time microbial turnover is leading to net immobilization. When calculated by the effects of organic nitrogen and carbon in the regression coefficients (Table 3) net immobilization during the first 15 days after incubation was estimated to occur at C/N ratios in the organic matter above c. 17 (excluding nitrate-N) in both experiments 2 and 3.

In both experiments 2 and 3 the main difference between mineralization from different plant materials

had appeared already after 15 days, whereas much smaller differences were found after that (Fig.4). In experiments 3, recovery 15 days after incubation varied between −17% and 16% of added nitrogen, whereas during the subsequent 173 days of the experiment recovery varied only between 25% and 36% of added nitrogen.

Discussion

Water tension control

The resistance of the ceramic cups to water movement was so low that even at a very high assumed water demand the water tension at the ceramic/soil interface would rise only slightly. The measurements were made after the cups had been inserted in the soil for approximately a year, and as the resistance of such cups has been reported to rise during use (Frank et al., 1991), the result is thus likely to represent the highest resistance they have shown during the experiments.

Apart from the resistance of the ceramic cups the soil poses resistance to water movement, a resistance which will rise sharply as the soil dries out. This means that if the water uptake by the plant is high, soil resistance may limit the water supply to soil at a greater distance from the ceramic cup. If this becomes a problem, the solution will be to place more ceramic cups in each pot, not in order to increase their water supplying capacity, but to reduce the maximun distance from any point of the soil to the surface of a ceramic cup.

Water supply by diffusion through ceramic cups worked well in the present experiment, and soil water tension was kept within the range of -3.16 to -31.6 kPa assumed by the DAISY model to lead to maximum mineralization rates. Compared to methods with frequent weighing and rewatering each pot to an original weight, it allowed a constant and well defined soil water tension with much less labour.

Mineralization measurements

Early measurement of mineralization

The results of experiments 2 and 3 showed that considerable difference in nitrogen uptake until the first cut could be measured. The result of experiment 1 showed that care should be taken to secure sufficient nitrogen uptake capacity to obtain realistic results. If the uptake is limited not only by its availability but also by the uptake capacity of the plant, then initial plant size variation will add to the variation in measured nitrogen uptake. Differences in initial plant size was presumably a main reason for the rather large variation in early nitrogen recovery in the present experiments (Tabk 2). Before incubation the test plants should therefore be large enough to secure a high uptake capacity as compared to the amount of available nitrogen, but not so large that (variation in) their nitrogen content before incubation becomes important.

The results of experiment 1 show that nitrogen accumulation in roots and stubble did not seriously affect the measurements; as much as 83% of the nitrogen uptake between 3 and 15 days after incubation was recovered within the harvested shoots.

Due to the experimental procedure the plants had the potential to initiate nitrogen uptake from the incubated materials immediately alter incubation, and significant effects of incubating phacelia residues could be measured 3 days after incubation. This is probably due to the high nitrate content of phacelia; nitrate is easily mobile in the soil solution and can move fast towards the roots. Ammonium either from the hydrodlysis of urea or from mineralization is much less mobile. This means that the plant roots have either to grow to the sites of ammonium release or the ammonium has to be nitrified and thus become mobile, before the plants can use it. Either process takes time, and nitrogen from these sources will take longer time to become available for the test plants than nitrogen that is initially in nitrate form.

Based on these considerations, it seems unlikely that measurements of mineralization of much shorter periods than the 15 days used in the present experiments can give satisfactory results.

Fox et al. (1990), Marstorp and Kirchmann (1991), and Oglesby and Fownes (1992) all found that the major differences in mineralization between the tested plant materials was to be found within the first two weeks after incubation as it was also found in the present experiments. Together the results show that the applied method can yield realistic mineralization measurements shortly after incubation.

Measurements of immobilization

The method was found to be able to show immobilization of nitrogen. It is possible that this could have been done with a smaller addition of urea, but net immobilization of nitrogen over the first 15 days was found up to 17 mg N/pot, which is about one third of the

added urea-N. Further, a smaller amount of urea will make the mixing with the soil more inhomogeneous. If immobilization occurs within only one or two days (Ladd.,1992; Marstorp and Kirchmann, 1991), proper mixing between soil and urea is important as soil transport processes will be limiting the ailability of the nitrogen for the microorganisins.

The estimated C/N ratio of 17, above which net immobilization occurred during the first days, is close to the results of Marstorp and Kirchmann (1991), who found initial immobilization when legume plant materials had C/N ratios above c. 15. In experiment 2 nitrate N was estimated to be almost fully assimilated by test plants during the first 15 days, whereas in experiment 3 the assimilation of nitrate-N within the first 15 days was lower and not significantly different from that of organic nitrogen. This difference between experiments 2 and 3 may be due to the drying of the plant material, as this may have reduced the initial mobility of nitrate (see below).

Effect of amount and composition of incubated material

The amount of nitrogen added, at least if it was 100 mg N/pot or more, did not seem to influence the relative nitrogen mineralization rates. Therefore, the measured mineralization patterns must be due to the chemical composition of the incubated materials.

In experiment 2 fresh plant material was incubated, whereas in experiments 1 and 3 dried plant materials were used. The plant material was dried at only 60°C to minimize the chemical effect of drying. Still drying has been found strongly to influence the mineralization from plant material (e.g. Ito and Watanabe, 1985). This may be due to changes in decomposability or mobility of chemical species by drying. Such changes may in many situations be unimportant, but when incubating easily decomposable organic material it has been found that net immobilization processes are concentrated within the first 24 hours after incubation (Ladd et al., 1992; Marstorp and Kirchmann, 1991). In such a situation the transport processes of chemical species in the soil will be limiting the supply of nitrogen to the microsites of active immobilization, and large differences in concentrations of chemical species between the active sites and the bulk soil may arise.

The results of the present experiment do agree with results of Frankenberger and Abdelmagid (1985) and Marstorp and Kirchmann (1991) who found C/N ratios to be the most significant chemical factor determining nitrogen release, but others have found quite different results. It is to be expected that the significance of different chemical parameters will depend strongly on the condition under which the experiments are made; the range of decomposability and N concentrations in the plant material, the nitrogen availability from the soil, and whether shorter or longer term results are considered. When plant materials with very different decomposability are compared lignin content is likely to be an important parameter as found by Neely et al. (1991) whereas when comparing young plant material from catch crops it is unlikely to show much relation to nitrogen release.

Results, as those of Oglesby and Fownes (1992), showing low correlation between C/N ratio and mineralization rates, may be due to inhomogeneous plant materials (mixture of leaves and twigs). Mineralization will be determined by the C/N ratio of the material decomposing at any specifc time, and an average C/N ratio for fast decomposing leaves and resistant twigs may be without practical significance. At first, only the presumably low C/N ratio of the fast decomposing leaves should be considered.

In most experiments it has been found that C/N ratios are good indicators of relative mineralization from easily decomposable plant material, and that the main difference in mineralization, as mentioned above, is to be found already after two weeks in the soil. These results indicate that most of the plant material has been through microbial turnover within this period, leading to mineralization or immobilization dependent on their C/N ratio. Mineralization after this period then mainly depends on the turnover of the microbial biomass itself.

General

The method was found to be easy to work with, and yielded results in accordance with those obtained by others. The method made it possible to obtain mineralization measurements under well defined conditions, and to measure mineralization closer to the date of incubation than other incubation methods with test plants. Reductions in the experimental variance as compared to the present results are desirable. This may be obtained by using test plants with a higher initial size and by being careful to reduce variance in initial plant size.

For materials where the initial decomposition is as fast as with fresh plant material, it seems that factors as the degree of mixing with the soil (Jingguo and Bakken, 1990), particle size (Sims and Fredrick, 1970)

and drying (Ito and Watanabe, 1985) may strongly influence the course of mineralization. Therefore conditions should be chosen to be as realistic as possible with incubation of chopped fresh plant material rather than of dried and ground materials.

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