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DECOMPOSITION RATES OF LEGUME RESIDUES AND N-MINERALIZATION IN AN ULTISOL IN LAMPUNG

E. Handayanto[1], Y. Nuraini[1], P. Purnomosidi[1], M. Hanegraaf[2], G. Agterberg[2], J. Hassink[2] and M. van Noordwijk[2]

1. Department of Soil Science, Faculty of Agriculture, Brawijaya University, Malang
2. DLO-Institute for Soil Fertility Research, PO box 30003, NL 9750 RA Haren, the Netherlands.

ABSTRACT

Results of preliminary measurements of decomposition and N-mineralization from various sources of crop residues of leguminous cover crops and hedgerow trees are presented. Decomposition measurements in litterbags in the field were compared with those in a sheltered pot experiment and in 'decomposition tubes' installed in the field. For some residues also N mineralization under standard laboratory conditions was measured. For decomposition of pruning material of hedgerow trees the litterbag and the pot experiment gave similar results, showing a rapid decomposition of *Erythrina* prunings (50% loss of dry weight in approximately 3 weeks) and a slow decomposition of *Calliandra* and *Peltophorum* prunings (50% loss of dry weight in approximately 15 weeks). For residues of leguminous cover crops and fallen leaves of cassava intermediate rates of decomposition were established in the pot experiment (50% weight loss in about 4 and 7 weeks, respectively). The measurements in the decomposition tubes were hindered by waterlogging of the soil due to compaction when the tubes were installed. Residues of two *Calopogonium* species decomposed faster than those of *Mucuna* and *Centrosema*. Measurements of CO_2-production (respiration) confirmed this result.

N-mineralization was measured by sampling the soil under litterbags, in the pot experiment and in the decomposition tubes. The litterbag results show a 'flush' of nitrate due to decomposing tree litters and a slow but steady increase of ammonium content of the soil. The highest peak in mineral N was found after 4 weeks in *Calliandra*. Results for a *Mucuna* cover crop in between the hedgerows, showed a high mineral N-content of the soil at the moment that the cover crop was slashed. Decomposing *Mucuna* residues resulted in a moderate further increase. In the pot experiment mineral N accumulated without leaching or crop uptake. The highest N-mineralization was found for *Calliandra* prunings, followed by a *Calopogonium* crop residue. Measurements of mineral N in the decomposition tubes in the field showed relatively high mineral N-contents of the soil at the end of the

growth period of the cover crops, but showed a subsequent decline where a further accumulation was expected, as crop uptake and leaching were excluded. The possibility of denitrification under the conditions of measurement is discussed. For further studies in the field the litterbag method in combination with measurements of mineral N in the soil appears to be the most suitable. The laboratory incubation study showed that N mineralization per unit N content of the residue was well correlated with the overal C/N content of the residue. Materials with a C/N content higher than 23 showed net immobilization during a period of 160 days. Other parameters of the chemical composition did not increase the percentage of variance accounted for in this study. A further check on N mineralization from *Calliandra* seems necessary, however. Some data are presented on a chemical fractionation of soil organic matter for the topsoil of five long term experiments. The relatively high total N content of the forest soil was associated with a high C/N content of the acid soluble fraction.

INTRODUCTION

Decomposition of dead plant material can have a direct effect on crop growth, by mineralization of nitrogen, and an indirect one, by build-up of soil organic matter which may increase future efficiency of nutrient use. The two functions are partly complementary. Rapidly decomposing material of low C/N quotient contributes mainly by N-mineralization and slowly decomposing litters contribute especially to the build up of the soil organic matter pool. To predict which function can be expected from a particular type of litter and to design cropping systems with a balanced supply of organic inputs, information on the rate of decomposition and N-mineralization of various sources of litter is needed. For the N-mineralization not only the total amount during the growing season is important, but also the time pattern of N-release (and possibly immobilization), as this can be more or less synchronous with the demand for uptake by crops. The degree of 'synchronization' between N-supply and demand is important for the efficiency of nitrogen use, especially under conditions of high rainfall and leaching. Leaching problems are the more severe when crops are shallow rooted and when mineral nitrogen is present in the nitrate form (Van Noordwijk *et al.*, 1992). As environmental conditions can have a pronounced effect on decomposition rates, the measurements should be done as much as possible under field conditions.

The major determinant of the decomposition rate of crop residues is the C/N ratio, although the lignin content of the cell wall fraction and the content of polyphenolics, such as tannin, can modify the results (Alexander, 1977). Apart from the 'quality' of the litter, decomposition rates are determined by environmental conditions such as temperature and humidity (Jenkinson and Ayanaba, 1977; Ladd *et al.*, 1985) and the accessibility to soil macrofauna and soil microorganisms (Brussaard *et al.*, 1992). These factors are influenced by incorporating the litter into the soil, as compared to leaving them on the soil surface. Direct measurement of the rate of decomposition of surface applied litter is complicated by considerable spatial variability in amounts of litter present. Methods in which known amounts of litter are applied which can subsequently be quantitatively recovered, have a definite advantage. The method of isolating a certain amount of litter may, however, influence the results. In the internationally coordinated project on Tropical Soil Biology and Fertility (Anderson and Ingram, 1989) the use of 'litterbags' of standardized, coarse mesh size is recommended (Fig. 1A). The litterbag does not allow a complete direct contact of litter and soil, but the mesh size is large enough to allow the soil macrofauna to do their work. We decided to compare the results of litterbag studies with a pot experiment, in which known amounts of litter were applied to pots, kept under a shelter to avoid rainfall and too high temperatures (Fig. 1C). We further included measurements in 'decomposition tubes' inserted to the soil and covered by plastic to avoid rainfall and leaching (Fig. 1B). Table 1 summarizes some characteristics of the three methods. In all methods litter is placed on top of the soil, as happens in no-till cropping systems.

Decomposition of crop residues might be influenced by the conditions in the field during a subsequent crop (e.g. due to microclimate or the presence of other types of litter on or in the same soil). We therefore decided to include a comparison of the decomposition of a *Mucuna* cover crop in four treatments of a hedgerow intercropping trial.

A laboratory experiment with selected residues was started to evaluate the role of the tannin content as modifying factor on mineralization rates. As decomposition in the soil and in ruminants may both be determined by bacterial processes, standard methods for evaluating digestibility for cattle were applied to these residues.

MATERIALS AND METHODS

A description of the soil profile and climate can be found in Van der Heide *et al.* (1992) and Van Noordwijk *et al.* (1992), respectively. For a preliminary study of decomposition a number of contrasting litter types were chosen, relevant to a hedgerow intercropping field experiment (Sitompul *et al.*, 1992) and a cover crop/ maize/ soybean rotation experiment (Utomo *et al.*, 1992). In each case the amount of litter applied was close to that to be expected in the field. Table 2 presents sources of crop litter and amounts used in the three studies. In the presentation of the results we will concentrate on the loss of dry weight and on data on N-mineralization. For the loss of dry weight an exponential decay is to be expected and data are presented in a logarithmic form. The time required for a 50% loss of dry weight is a characteristic value.

Table 1. Comparison of three methods to study decomposition and N-mineralization (Fig. 1).

	Litterbag	Decomposition	Pot experiment tube
Soil undisturbed	no	slight	yes
Contact litter/soil	indirect	direct	direct
Macrofauna excluded	no	yes	yes
Leaching	yes	no	no
Crop uptake	no	no	no
Control of water content	no	no	yes
N-balance measurement	no	yes	yes

Table 2.Sources of crop litter and amounts used in the three studies.

Sources of litter	Quantity of litter Mg/ha		
	Litterbag	Tube	Pot
Calliandra calothyrsus	1.2	-	2.3
Erythrina orientalis	1.0	-	0.9
Peltophorum pterocarpa	1.0	-	2.1
Mucuna/Calliandra	1.1	-	-
Mucuna/Erythrina	1.1	-	-
Mucuna/Peltophorum	1.1	-	-
Mucuna pruriens	-	1.1	2.7
Calopogonium caeruleum	-	1.6	-
Centrosema pubescens	-	1.4	-
Calopogonium mucunoides	-	1.7	2.2
Imperata cylindrica	-	0.6	-

Litter bag experiment

The experiment was carried out in a hedgerow intercropping field experiment (Sitompul *et al.*, 1992), consisting of a random block design with 7 treatments and 2 replicates. For measuring the absolute decomposition rates of pruning materials, standard litter bags (Anderson and Ingram, 1989). These are made of exuded polyvinyl with a 7 mm mesh. The sides of the bag were bent up to retain the shape of a shallow box-like container, 30 X 30 X 2.5 cm. The bags were located randomly in the field on top of the soil. One bag was retrieved, randomly chosen, from each replicate after 0, 2, 4, 6, 8, 12 and 16 weeks. At each sampling occasion, the bags were carefully lifted in the field to reduce losses of fragmented residues and enclosed in separate polytene bags for transport to the laboratory for measuring dry weight. Soil samples were collected from the sites where bags had been removed, from 0-5, 5-10 and 10-15 cm depth and KCl extracts were made to measure ammonium and nitrate N in the soil, at all sampling occasions.

Decomposition tube experiment

A field incubation experiment was carried out in the existing cover crop experiment of N project (Utomo *et al.*, 1992). Plots were selected with the leguminous cover crops *Mucuna pruriens utilis, Centrosema pubescens, Calopogonium caeruleum,* and *Calopogonium mucunoides*; a grass/weed control plot containing *Imperata cylindrica* was included in this study. An in-situ incubation method of Tropical Soil Biology and Fertility programme (Anderson and Ingram, 1989) was used. Plastic tubes (45 mm internal diameter) were used to take initial soil samples and to isolate soils during field incubation. The tubes were inserted into the soils in pairs within an area of about 1 m2, with the pairs located randomly at the site. The cores were then pushed in at the depth of 35 cm, with 5 cm of tube projecting above the soil surface. One of the tube of each pair was filled with cover crop residues. Loss of weight of plant materials was measured using a modified mesh bag with a 2 mm mesh size, filled with 50 gram of fresh plant material as initial weight, placed on top of the soil, inside the tube. One tube of each pair was removed immediately for determining mineral-N concentrations in the soil (time zero) and the remaining tube was covered with a plastic cup to protect the core from rain. Of the remaining core a KCL extract was made to determine the mineral N concentration after 2, 8, and 16 weeks for each site. The cores were sectioned by depth (0-10, and 10-20 cm). Each soil sample (5 g) was extracted in a 1: 10 soil: solution ratio with KCL (2 M). To each sample 2.5 ml Toluene was added to avoid N transformations during sample transportation. The concentration of ammonium-N and nitrate-N was measured. Samples were taken at two weeks interval and dried at 65°C. Carbon evolved during the process of decomposition was also measured using the method of Anas (1989).

Pot Experiment

A pot experiment was conducted in the field, sheltered by a grass thatched roof. Plastic pots were filled with 5 kg of air-dried soil, sieved with a 2 mm mesh sieve. Water was added to approximate field capacity. Five legume residues i.e. *Mucuna pruriens* var. utilis, *Calopogonium mucunoides, Calliandra calothyrsus, Erythrina orientalis* and *Peltophorum pterocarpa*, were selected for this study (Table 2). All materials were chopped to equal size and placed on the surface of the pots. One series of control pots was started. During the experiment, pots were weighed frequently and water was added to maintain field capacity. A complete randomly design was used with 7 treatment and three replicates. Harvest times were 0, 2, 4, 6, 8, 12 and 16 weeks. At each harvest, plant residues were separated from the soil, dried and weighed. Soil samples were collected from the depth of 0-5 cm, 5-10 cm and 10-15 cm for each pot. KCL extracts of the soil were analyzed to determine ammonium-N and nitrate-N in the soil.

Laboratory N mineralization measurements

For 13 types of residue N mineralization was also measured under laboratory conditions, using the method of Stanford and Smith (1972). 'Leaching tubes' of 2.5 cm diameter were filled with 50 g of soil (a 1:1 mixture of quartz sand and top soil from Lampung) and brought to 50% of water holding capacity (WHC) by adding 10 ml of water. Residue

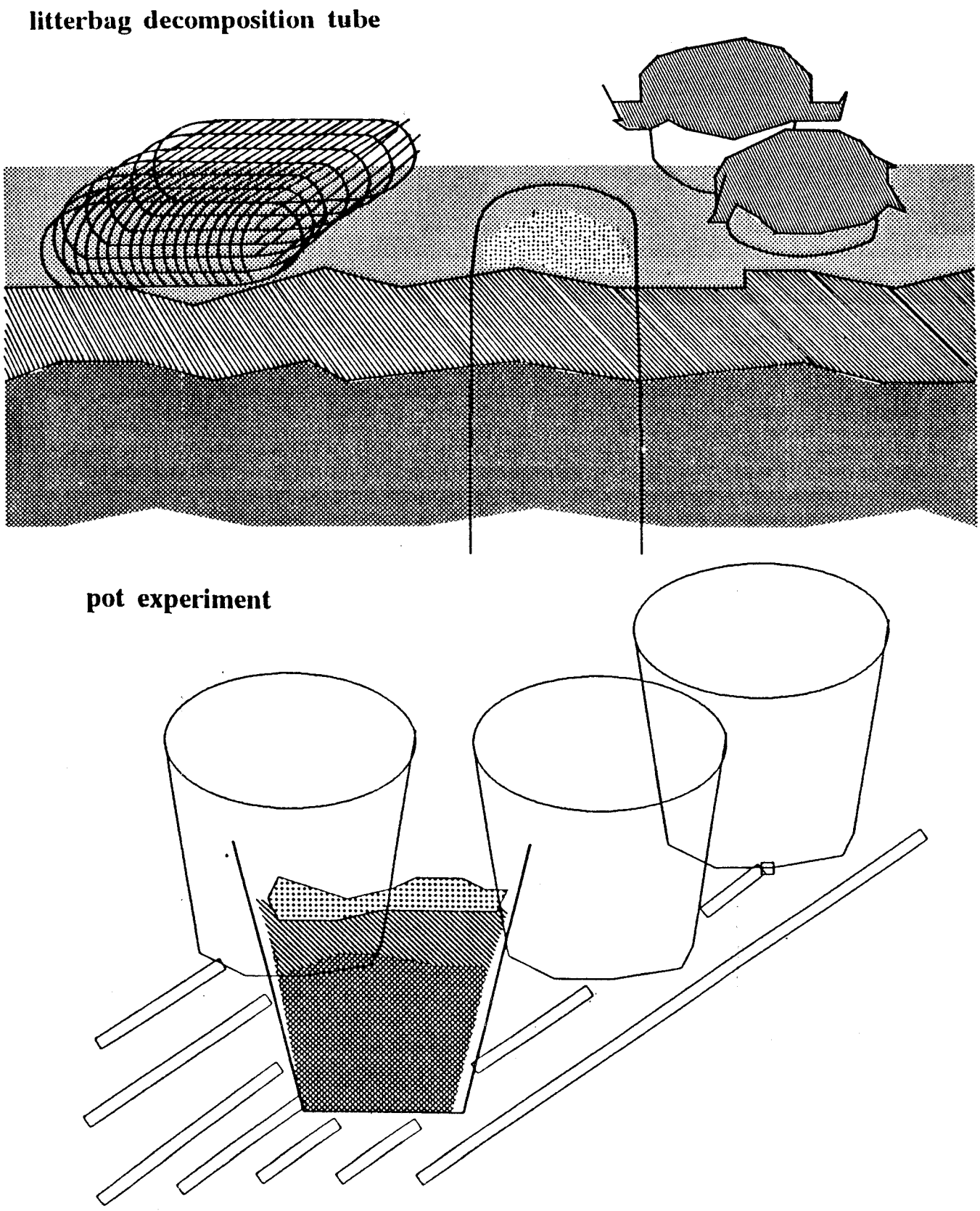


Figure 1. Schematic presentation of litterbag, decomposition tube and pot experiment.

samples, 1 g per tube, were mixed through the soil. A filter was placed at the bottom of the tube and a glasswool pad on top. Tubes were kept in a climate room at 25°C. At 0, 2, 4, 8, 16 and 32 weeks tubes were sampled by leaching with a 0.01 M $CaCl_2$ solution, in 10 increments of 10 ml. After leaching 25 ml of a solution containg 0.002M $CaSO_4$, 0.002 M $MgSO_4$, 0.005 M $Ca(H_2PO_4)_2$ and 0.0025 M K_2SO_4 was added to each tube and the soil was brought back to 70% of WHC. The quantity of N leached was considered to be the amount of N mineralized in the period between two sampling occasions. Control tubes without plant residues were included and used for corrections.

As we expected that tannin content may modify N-mineralization, residues were included for which a high tannin content was expected: *Peltophorum*, *Desmodium heterophyllum* (locally abundant and a candidate for a shade-tolerant cover crop) and *Desmodium ovalifolium*, grown under glasshouse conditions. Table 3 shows some data on chemical composition of selected crop residues, using methods developed for predicting digestibility for cattle. On the basis of the NDF (neutral detergent fibre) method a distinction between easily decomposable material (1 - NDF) and structural material (mostly cell walls) can be made. Cellulose and hemi-cellulose can be estimated from NDF - ADL (acid detergent lignin). By measuring the N content of the NDF fraction, an estimate of the C/N ratio of the easily as well as the structural material can be made. The thirteen types of residue chosen for this study show considerable variation in composition. The highest tannin content was found for leaf material of *Peltophorum pterocarpa*. The local leguminous *Desmodium heterophyllum* has a relatively high tannin content as well, higher than that for the glasshouse grown *Desmodium ovalifolium*. The estimated C/N ratio for the 'easily decomposable' fraction of stem material is higher than that for the 'structural' fraction of several types of leaf material.

RESULTS

Loss of dry weight

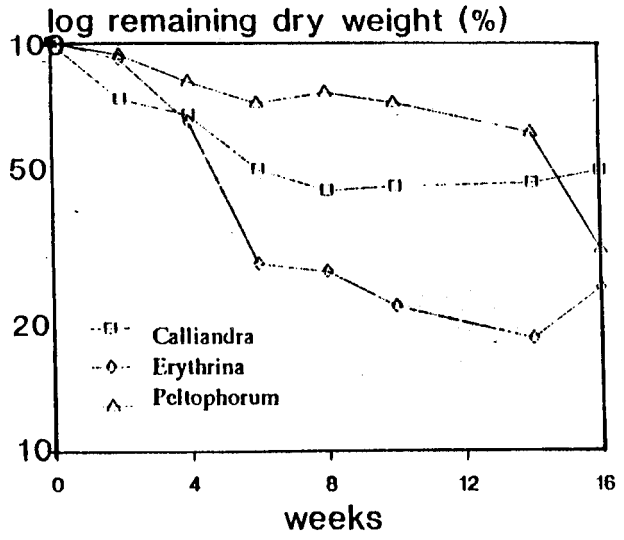
Figure 2A shows, on a logarithmic scale, the dry weight remaining in the litterbags sampled over a period of 16 weeks. Overall a linear downward trend is indicated, representing exponential decay of the litter. For *Erythrina* the decomposition apparently slows down when about 20% of the original amount is left, for *Calliandra* this happens when about 45% is left and for *Peltophorum* when 70% is left, although the last measurement was deviating. In figure 2B the data of figure 2A are compared with results of the pot experiment for the same litter types. In the pot experiment a relatively large decrease of dry weight was found in the first measurement, two weeks after the start of the trial, with a slow but steady subsequent decline. Despite this difference in pattern, the two methods agree in showing a rapid decomposition of *Erythrina*, and a slower one for *Calliandra* and *Peltophorum*. Combining the two methods, we may estimate the time required for 50% loss of dry weight for the litters to be about 3, 15 and 15 weeks, respectively.

Figure 3 shows the loss of dry weight in the pot experiment for all litter types. The decomposition of the leguminous cover crops *Calopogonium* and *Mucuna* was relatively fast (50% loss of dry weight after approximately 4 weeks), that for fallen leaves of cassava intermediate (50% loss of dry weight after approximately 7 weeks). The data on loss of dry weight in the decomposition tubes proved to be very irregular after 8 weeks; in figure 4 only the first four measurements are presented. The data indicate a rapid decomposition by *Calopogonium* residues (both species) and a relatively slow decompositions of *Mucuna*, *Centrosema* and *Imperata* residues. Overall, decomposition was slower than in the pot experiment. This may be caused by the partial waterlogging. Figure 5 shows the respiration rate measured in decomposition tubes with various types of litter. No correction for background soil respiration was made. For all litters the respiration showed a strong decrease over time. Respiration rates decreased in the order: *Calopogonium caeruleum* > *Calopogonium mucunoides* > *Centrosema pubescens* > *Mucuna pruriens* > *Imperata*.

N-mineralization

Figure 6 shows the mineral N content of the soil under litterbags filled with *Mucuna* residue, placed in four treatments of the hedgerow intercropping period during a maize crop, following *Mucuna*. No indications were obtained that the pattern of N-release was influenced by the type of litter present in this plot. In figure 7D the results are averaged over theses four treatments. At the start of the litterbag experiment mineral N-content of the soil was found to be rather high. At 4 and 6 weeks after the start only a moderate increase in mineral N was measured; in fact the NH_4 content decreased while the NO_3 content more than doubled. After the maize harvest, 16 weeks after the start of the litterbag experiment, virtually no nitrate remained in the soil, while ammonium was still close to the original value.

Figure 7A, B and C show mineral N-contents of the soil in a different episode of the hedgerow intercropping experiment. During this series of measurements mineral N content of the soil was low initially, with hardly any nitrate present. During decomposition of the prunings a 'flush' of nitrate could be measured at 4 and 6 weeks which had disappeared by 16 weeks. The ammonium content of the soil showed a slow but steady increase. In all measurements included in figure 7 mineral N was more or less evenly distributed over the three layers sampled. The peak in mineral N-con-



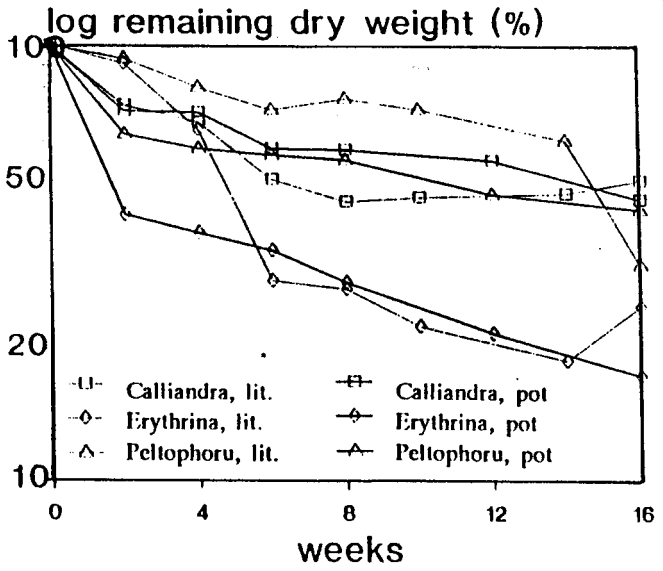


Figure 2. Loss of dry weight by prunings of three species of hedgerow trees (C = Calliandra, E = Erythrina, P = *Peltophorum*). A. measured in litterbags, B. measured in a pot experiment.

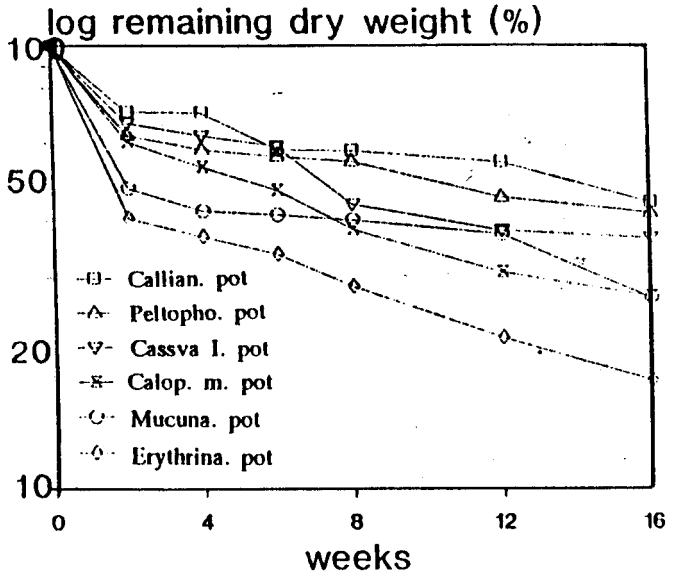


Figure 3. Loss of dry weight of six types of plant litter in the pot experiment.

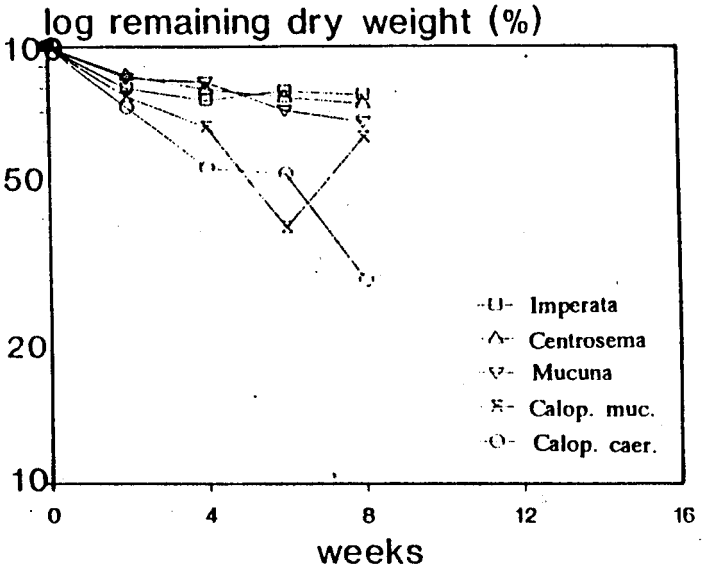


Figure 4. Loss of dry weight of five types of plant litter in decomposition tubes; results after 8 weeks are omitted, because of irregularities in the data.

tent was measured at 4 weeks for *Erythrina* and *Calliandra* and at 6 weeks, but less pronounced, for *Peltophorum*. In the interpretation of the data we have to realize that crop uptake and leaching were leading to a decrease of mineral N, especially NO3, while mineralization of both soil organic matter, root residues and the litter in the litterbag lead to an increase. No measurements in a situation without recent litter inputs were made.

Figure 8A till D shows the mineral N measured in the pot experiment, without the presence of a crop and without leaching. Now a gradual build-up of mineral N is observed, relatively fast for *Calliandra* and relatively slow for *Peltophorum*. In interpreting the absolute amounts we have to take the different amounts of litter, as well as the different N-contents of the various litter sources. The ammonium content of the soil shows no consistent change while the nitrate content increased, so apparently nitrification of N mineralized occurred rapidly. Although the four measurements obviously do not show the whole pattern, figure 8F suggests for shed cassava leaves an initial immobilization, followed by N-release before 8 weeks.

In the decomposition tubes crop uptake was excluded while the cover of the tubes prevented leaching, so an accumulation of mineral N could be expected. The measurements in figure 9 show otherwise. Mineral N content was rather high initially, at the end of the growing period of the cover crops, but decreased sub-

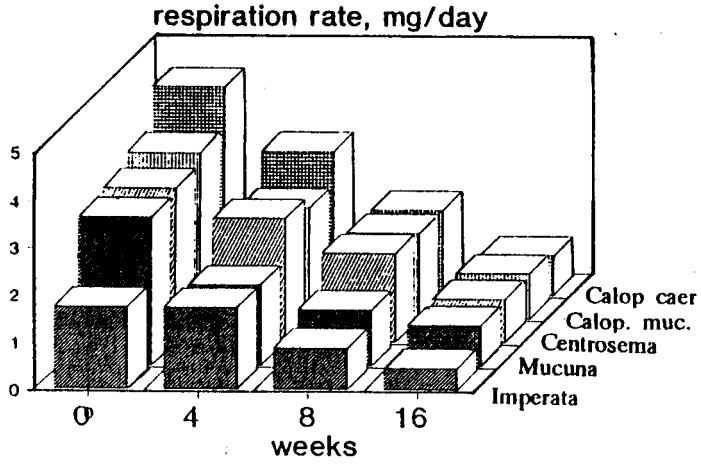


Figure 5. Respiration rate (CO_2 evolution) as measured in the decomposition tubes for four periods.

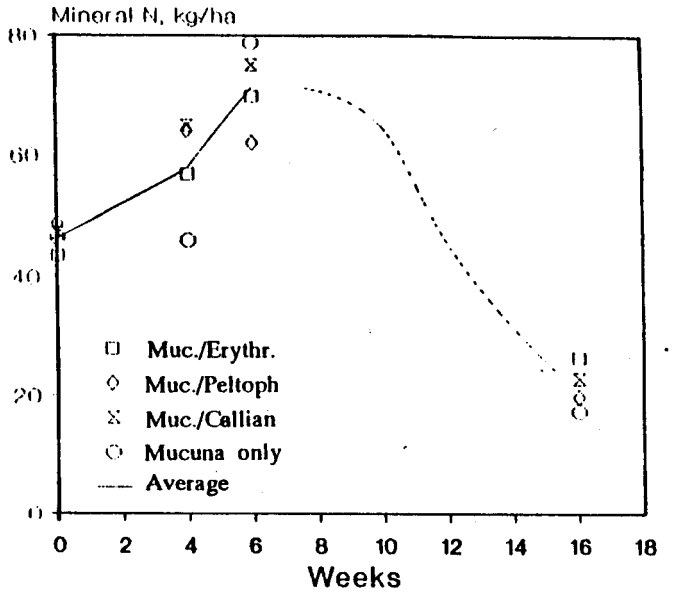


Figure 6. Mineral N content of top soil (0 - 15 cm; ammonium plus nitrate) underneath litterbags with *Mucuna*, in four treatments of a hedgerow intercropping trial, three with hedgerow trees and one in a control plot, without trees.

sequently through a loss of nitrate. The data are rather irregular, however, as noted for the loss of dry weight of the litter samples as well. In interpreting the data we have to consider the possibility of denitrification as reason for the loss of nitrate. Due to physical disturbance and compaction of the soil during installation of the tubes, the soil in the tubes was often waterlogged after heavy rain, despite the cover on the tube. Water must have entered through the bottom of the tube during temporary ponding of the field during heavy rainfall. Subsequently conditions for denitrification were probably met: presence of nitrate and carbon substrate, high temperature and lack of oxygen due to water logging. Variations in degree of waterlogging, though not recorded, might be responsible for the high variability of results.

N mineralization was also measured in the laboratory, under standard conditions. Figure 10 A and B shows N mineralization (corrected for that in control soil), expressed as fraction of the initial total N content. Immediately after incorporation some mineral N was present for the stem samples, but later on N immobilization dominated. The material collected as forest litter also led to immobilization of N. All except one, *Desmodium heterophyllum*, of the leaf samples led to net mineralization of N.

Figure 11 shows that the specific net mineralization rate over a period of 160 days was well correlated with the initial C/N ratio. No improvement of the varaiance accounted for was obtained by including any of the parameters in Table 3 in a multiple regression model. Only a slight indication was obtained for a role of tannins in modifying net N mineralization.

Table 3. Chemical properties of plant residues used for mineralization study. All measurements except for C/N ratios are expressed as % of dry weight. C/N-t, C/N-e and C/N-s refer to total, easily decomposable and structural biomass respectively

	NDF	NDF-iv	ADF	ADL	IVTD	IVCWD	Tan
Forest litter	65.5	62.4	72.1	36.3	15.7	4.8	1.45
Stem							
Peltophorum pteroc.	79.6	72.9	69.7	17.0	20.7	8.4	1,35
Leucaena leucoceph.	83.7	73.7	69.6	14.8	24.4	11.9	0.10
Cassava	73.8	53.7	55.1	12.8	44.8	27.2	0.10
Mucuna pruriens	64.2	44.8	54.2	13,2	51.2	30.1	0.80
Desmodium heteroph.	69.9	57.2	55.0	17.8	37.6	18.2	1.06
Desmodium ovalifolium	63.7	43.7	52.3	10.8	49.7	31.4	0.52
Leaves							
Peltophorum pteroc.	62.5	62.1	56.4	21.1	19.7	0.6	5.96
Leucaena leucoceph.	45.9	36.3	33.1	14.8	48.5	20.9	1.54
Cassava	40.5	19.0	55.5	21.9	59.2	53.1	1.70
Mucuna pruriens	55.8	36.9	55.2	19.8	52.9	33.8	0.86
Desmodium heteroph.	58.2	53.6	45.0	12.1	32.4	7.9	3.84
Desmodium ovalifolium	42.5	22.1	41.3	9.8	64.6	47.9	2.77

	N-tot	N-NDF	N-ADF	Ash	C/N-t	C/N-e	C/N-s
Forest litter	1.16	0.51	0.30	7.17	41.9	42.9	58.3
Stem							
Peltophorum pteroc.	0.81	0.51	0.56	3.24	57.4	33.4	91.2
Leucaena leucoceph.	1.04	0.71	0.39	4.14	39.3	16.1	57.9
Cassava	1.22	0.56	0.45	4.34	37.0	20.8	81.1
Mucuna pruriens	1.32	0.56	0.38	5.74	32.7	17.7	77.1
Desmodium heteroph.	1.27	0.57	0.47	4.51	35.0	19.0	79.6
Desmodium ovalifolium	1.99	0.84	1.17	5.26	21.5	11.1	84.3
Leaves							
Peltophorum pteroc.	2.83	2.07	1.36	3.73	17.2	10.3	23.5
Leucaena leucoceph.	4.78	3.08	1.06	7.64	10.5	7.6	16.3
Cassava	4.73	2.76	1.55	6.20	10.9	5.9	18.7
Mucuna pruriens	4.47	3.53	2.25	5.83	10.6	6.6	13.4
Desmodium heteroph.	2.15	1.24	0.61	7.82	21.3	13.5	36.9
Desmodium ovalifolium	3.70	0.93	1.15	7.85	12.6	8.5	50.2

NDF (neutral detergent fibre) = (hemi)cellulose, (lignin, cutins),
NDF-iv = in vitro determination of NDF,
ADF (acid detergent fibre) = cellulose, lignin, cutins,
ADL (acid detergent lignin) = lignin, cutin, (tannins)
IVTD (in vitro true digestibility) = weight loss during 48 h incubation in stomic acid (Tilly & Terry),
IVCWD (in vitro cell wall digestibility) (Van Soest),
Tan = tannin (polyphenolics).

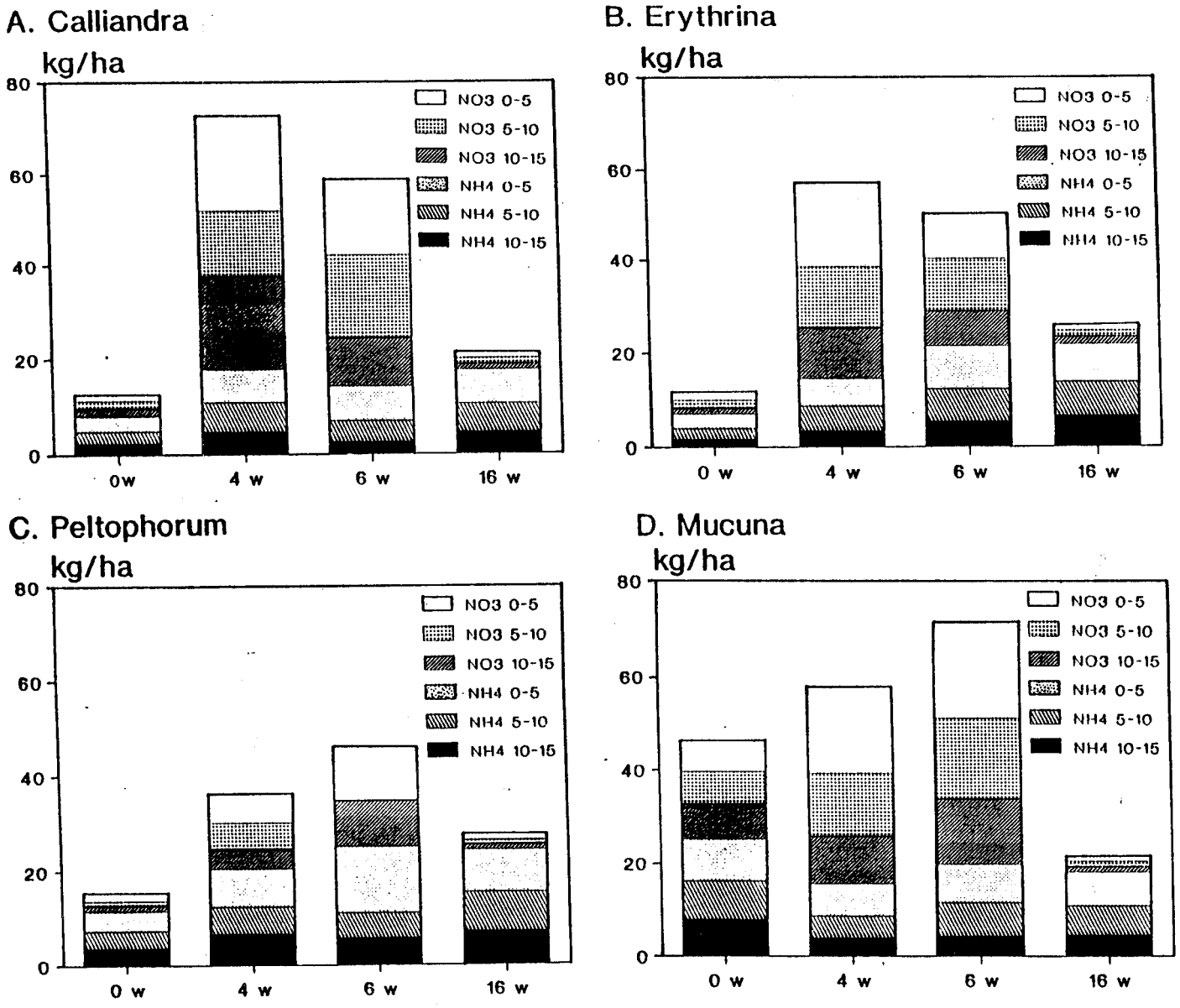


Figure 7. Mineral N content in the top soil of a hedgerow intercropping experiment, underneath litterbags with *Mucuna*. The first measurement coincided with planting, the last with harvesting of a maize crop. A. *Calliandra*, B. *Erythrina*, C. *Peltophorum*, D. *Mucuna*.

The results of a fractionation of soil organic matter (Table 4) can be partly understood from the quantity and quality of organic inputs in the various cropping systems. Repeated measurements throughout a growing season, however, are necessary to understand the dynamics of soil C and N content. The data suggest that none of the cropping systems is able to maintain the C_{org} content of forest soil.

Table 4 Soil analysis of topsoil (0-5 cm) samples of long term soil fertility experiments and undisturbed forest soil. Resp = respiration in 50 days at 20°C.

Vegetation or Species	Total C & N			Acid-soluble			Resp	Microbial Biomass	
	%Nt	%Corg	C/N	%Nt	%Corg	C/N	%of Corg	mg/kg (1°)	% Nt
Forest	0.187	4.7	25.5	5.43	4.33	20.3	1.64	38.5	2.06
Maize	0.127	3.38	26.7	28.8	5.63	5.53	2.83	28.4	2.24
Rice	0.140	4.44	31.8	33.5	5.95	5.65	0.96	17.4	1.24
Mucuna	0.133	3.78	28.5	10.7	3.63	9.75	0.59	-	-
Control	0.113	3.46	30.6	11.9	3.58	9.83	1.32	-	-
Peltoph	0.133	3.88	29.1	30.2	3.95	3.96	1.99	-	-

Maize and rice: Cassava/maize and Cassava/rice intercropping plots (Experiment 1) receiving an annual N fertilizer rate of 60 kg/ha, *Mucuna*: *Mucuna*/Maize rotational system (Experiment 2), Control: weed fallow/Maize rotational system (experiment 2), *Peltoph*: Hedgerow intercropping trial with *Peltophorum* and maize (experiment 3). 1°=mg Microbiol biomass per kg of dry soil

DISCUSSION

Comparison of the results for the three methods used in the field shows that the litterbag study and the pot experiment generally showed consistent results for loss of dry weight of litters. Results for N-mineralization are not in contradiction when the probable effects of leaching and crop uptake in the litterbag study are ac-

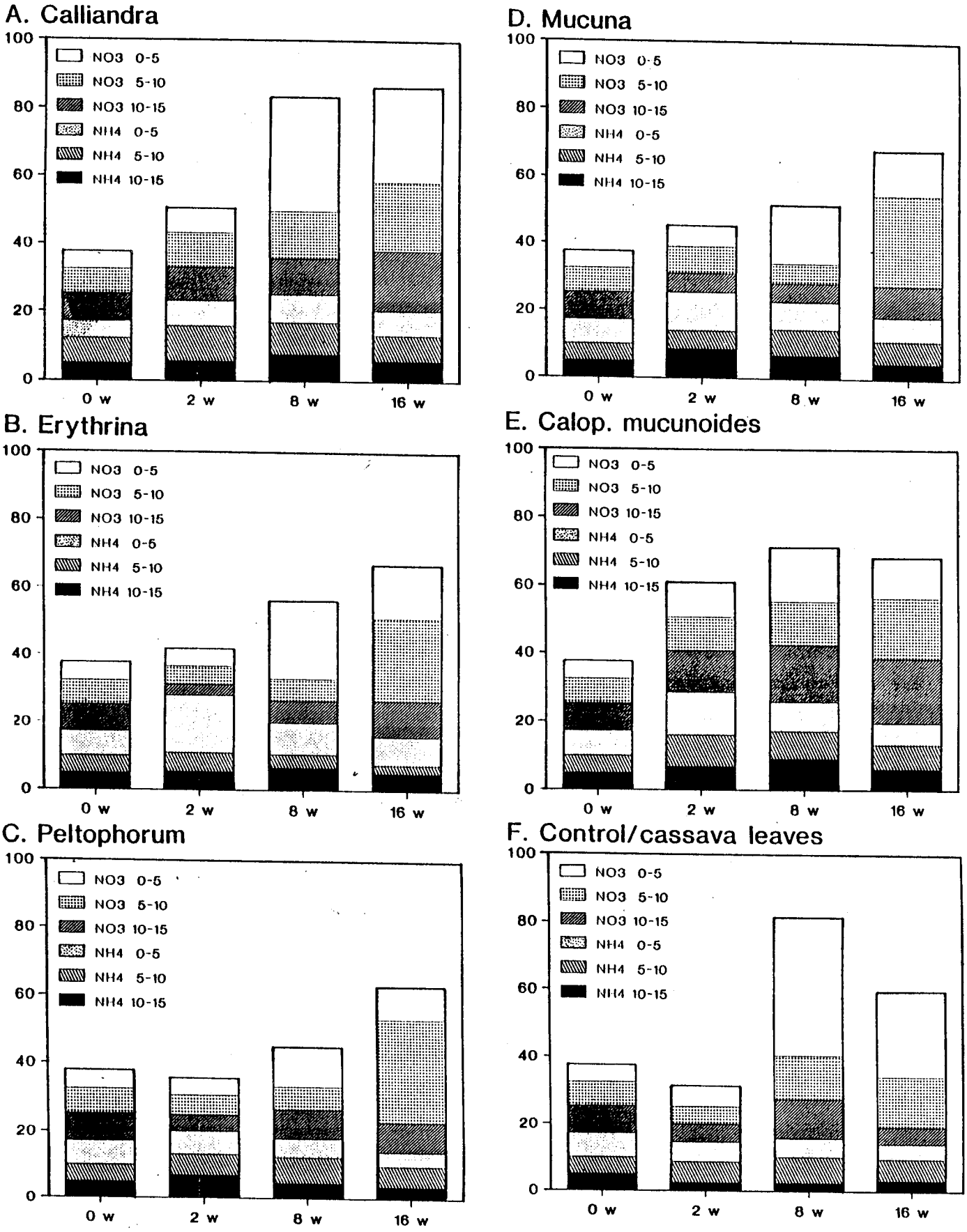


Figure 8. Mineral N in the soil of a pot experiment with six types of decomposing crop litters on the surface. A. Calliandra, B. Erythrina, C. Peltophorum, D. Mucuna, E. Calopogonium mucunoides, F. Cassava leaves.

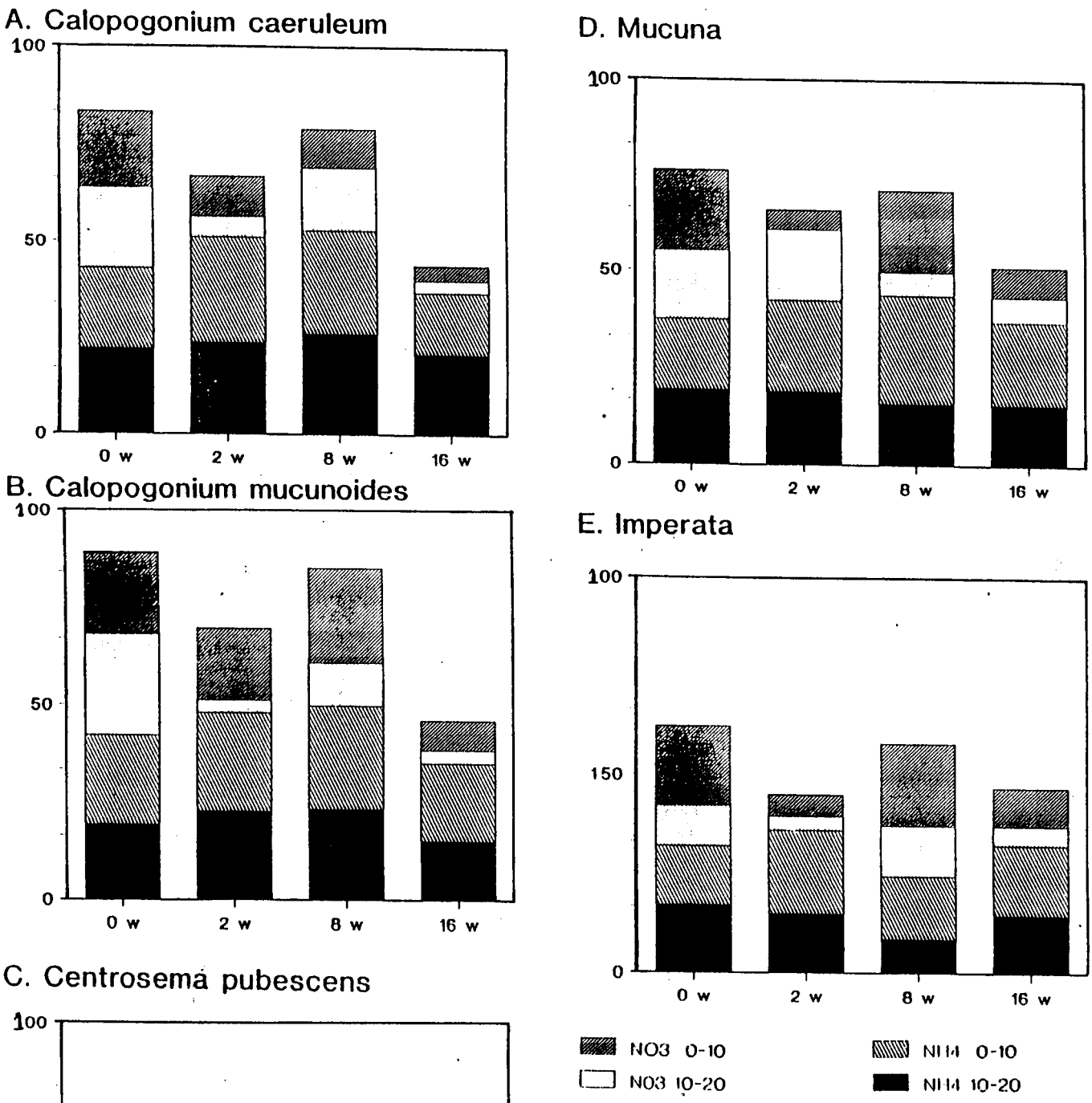


Figure 9. Mineral N content of soil in the decomposition tubes (0-20 cm). A. *Calopogonium mucunoides*, B. *Calopogonium caeruleum*, C. *Centrosema pubescens*, D. *Mucuna pruriens var. utilis*, E. *Imperata cylindrica*.

counted for. For further studies the pot experiment approach has the advantage that an N-balance can be made, while the litterbag study in combination with mineral N sampling shows the complexity of the real field situation. The choice of methods should then depend on the purpose of the research. The pot experiment approach can be combined with growing a crop, although the water balance of the soil is more difficult to control in that case. The litterbag study requires considerably less effort. The decomposition

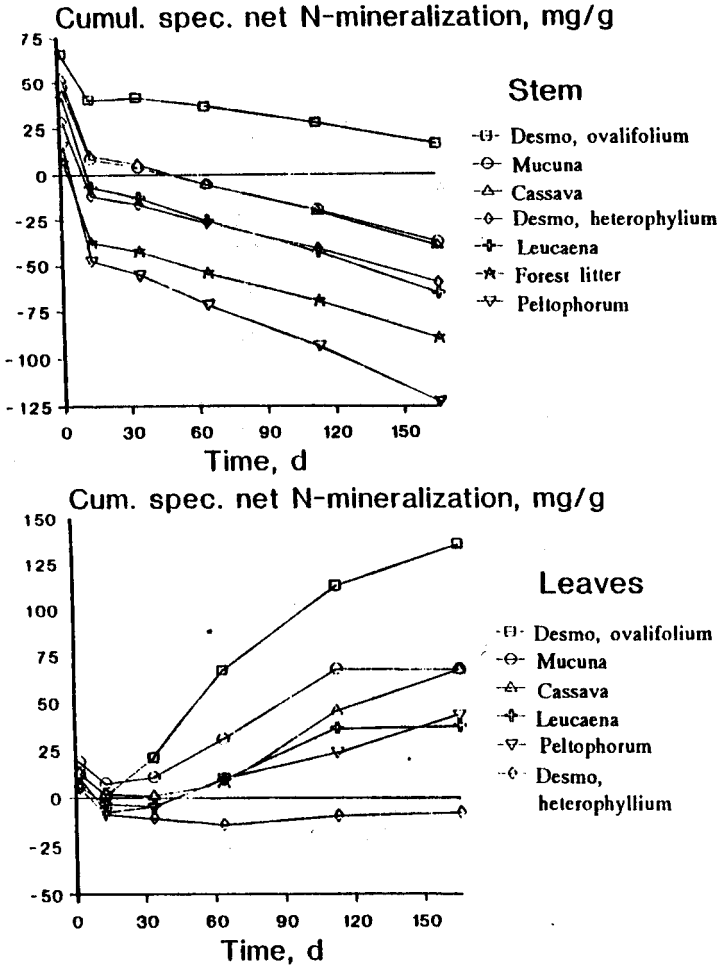


Figure 10. A and B. Cumulative net N mineralization per unit N content for stem and leaf material in the laboratory at 25 °C.

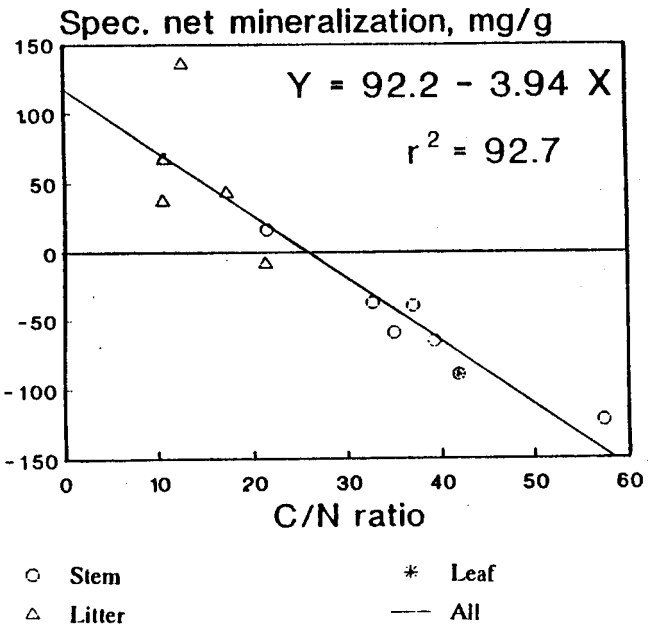


Figure 11. Relation between C/N content of stem and leaf litters and net mineralization per unit N in a period of 160 days.

tubes, which were supposed to combine certain advantages of both types of approach, failed to give consistent results in our case. The loss of dry weight was slower and a depletion of soil nitrate content, in stead of the expected accumulation, were recorded. As discussed above, these results are probably due to water-logging in the tubes. For future measurements of this type the installation of the tubes should be considerably improved.

Despite the weaknesses of the various methods, results show considerable variation in decomposition rates of the different litter types. The most rapid decomposition was recorded for *Erythrina* prunings, in agreement with its high N-content, the slowest for *Calliandra*, despite its high N-content, and for *Peltophorum* with a low N-content. For the leguminous cover crops relatively rapid decomposition is in agreement with their high N-content. Cassava and *Imperata* residues of relatively low N content had a relatively slow decomposition. For *Calliandra* these results indicate that an other factor than C/N ratio was determining the decomposition rate in the field. Palm and Sanchez (1990) reported a high decomposition rate for *Erythrina* prunings with a low content of polyphenolics (1.0) and a slower rate for *Inga* and *Cajanus* with a polyphenolic content of 3.4 and 3.3%, respectively. In Nigeria *Calliandra calothyrsus* was found to have the highest polyplenoloc content (5.6%) of twelve tree species measured (Tian Guanlong, pers. comm.). Although the present laboratory experiment did not indicate tannin (polyphenolic) content to modify mineralization rate, *Calliandra* was not included in that series and further experiments are needed. Interestingly, the combination of a high N-content and a slow decomposition leads to both a considerable contribution to crop N-nutrition and a large residue, adding to the organic matter content of the soil. *Calliandra* litter might thus form a good compromise between the two functions of litter inputs. A possible drawback, however, of the apparent 'decomposition inhibitors' in *Calliandra* is that they may have allelopathic effects on germinating food crops. Although not leading to crop failure, in the establishment phase maize is definitely hindered by *Calliandra* prunings.

Anyhow, these results show that decomposition rates and patterns of N-release should be studied under field conditions, as unexpected results can still be found.

The results of a fractionation of soil organic matter (Table 4) can be partly understood from the quantity and quality of organic inputs in the various cropping systems. Repeated measurements throughout a growing season, however, are necessary to understand the dynamics of soil C and N content. The data suggest that none of the cropping systems is able to maintain the C_{org} content of forest soil.

CONCLUSION

In the litterbag and in the pot experiment, *Erythrina*

prunings showed a rapid decomposition while Calliandra and *Peltophorum* prunings showed a slow decomposition. Intermediate rates of decomposition were established for residues of leguminous cover crops and fallen leaves of cassava in the pot experiment. In the decomposition tubes, residues of two *Calopogonium* species decomposed faster than those of Mucuna and *Centrosema.*

The litterbag results showed a 'flush' of nitrate due to decomposing tree litters and a slow but steady increase of ammonium content of the soil. The highest peak in mineral N was found after 4 weeks in *Calliandra.* Results for a *Mucuna* cover crop in between the hedgerows, showed a high mineral N-content of the soil at the moment that the cover crop was slashed. Decomposing *Mucuna* residues resulted in a moderate further increase. In the pot experiment, the highest N-mineralization was found for *Calliandra* prunings, followed by a *Calopogonium* crop residue. Measurements of mineral N in the decomposition tubes showed relatively high mineral N-contents of the soil at the end of the growth period of the cover crops, but showed a subsequent decline where a further accumulation was expected, as crop uptake and leaching were excluded. For future studies the litterbag method in combination with measurements of mineral N in the soil seems to be the most suitable method.

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