NOTES

POTENTIAL SOIL NITROGEN MINERALISATION AS INFLUENCED BY TREE CANOPY DEVELOPMENT

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Keeney's publication in 1980 thoroughly reviewed the nitrogen (N) cycle in forest ecosystems. One conclusion the author discussed concerns the immobilisation-mineralisation processes that contributed to the N availability in soils. Other findings also showed biological mineralisation of soil organic N as a good index for predicting the power of soils to supply N (Weier & MacRae 1993, Manguiat *et al.* 1994). Nitrogen mineralisation is affected by N fertilisation or by the elimination of N uptake such as after forest harvesting. Below-ground N cycling patterns play a vital role in regulating nitrate leaching (van Miegroet *et al.* 1992). Increases in soil temperature following clear cutting have always been suggested to cause an increase in N mineralisation and nitrification (Matson & Vitousek 1981). However, other factors such as substrate availability and soil acidity are more prominent in regulating microbial activity within the soil (Holmes & Zak 1994). The present article reports findings from chronosequent experiments on soils collected from a newly established *Acacia mangium* plantation. The experiments were conducted to study the mineralisation and nitrification potentials of soils under and between the tree canopies at different stand ages.

The sampling plot for this study was established within a 0.24-ha area in an *A. mangium* plantation in Kemasul Forest Reserve, Pahang. The potential soil mineralisation was assessed through a series of measurements from a stand age of 8 to 26 months. The variables examined were canopy cover and depth of soil profile. The soil in the area was classified as Aquoxic Tropudult with pH less than 4.5 and low cation exchange capacity (Table 1). Composite soil samples, each from 10 random subsamples, were taken using soil auger at four different depths, 0–5 cm, 5–15 cm, 15–30 cm and 30–45 cm, under and between the tree canopy at four different growth intervals.

Table 1 Chemical and physical properties of the soil

Depth (cm)	TOC (%)	N (%)	C/N	pH	CEC ($cmol_c\ kg^{-1}$)	Clay (%)	Silt (%)	Sand (%)
0–5	0.73	0.10	7.30	4.28	4.75	32	27	42
> 5–15	0.63	0.09	7.00	4.22	3.35	32	27	37
> 15–30	0.34	0.07	4.86	4.16	2.28	44	21	36
> 30–45	0.22	0.06	3.67	4.12	3.62	38	31	33

Results are based on dry soils; TOC – total organic carbon; CEC – cation exchange capacity

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These samples were assessed for their potential mineralisation capacity through laboratory incubation at 30 °C (average temperature of the site). A total of 20 g dried samples from each composite soils were placed in 100 ml plastic vials. Deionised water was added to bring the moisture content to two-thirds field capacity. These vials were covered with parafilm and placed in an incubator. The incubated samples were checked every week to avoid anaerobic condition and to correct for any loss of moisture detected by weight difference. The experiment was carried out in triplicate with five batches.

For nitrification potentials, soil samples were preincubated at half field capacity for one week prior to enrichment with 100 $\mu g\ N\ g^{-1}$ of soil in form of ammonium solution at two-thirds field capacity. Each batch of samples was withdrawn from the incubator at 0, 1, 2, 3 and 4 weeks after incubation. KCl solution (1 N) was added to each vial, with the volume adjusted to give a total aqueous solution of 40 ml. The mixture was shaken for one hour, centrifuged and filtered through Whatman no. 42 filter paper. The aliquot was collected for the determination of ammonium and nitrate N using Nessler distillation method. Calculation was done on per week basis for standardisation.

Results were analysed statistically based on analysis of variance and mean separation test.

Table 2 presents the changes in mineral-N concentration in the soil throughout the four weeks incubation period at different stand ages. The negative values denote net immobilisation. All the three parameters studied, namely, soil depth, tree canopy and age of plantation, have important influence on the nitrogen transformation in this soil. At stand age of 8 months, soil mineralisation rate differed between soil depths with the highest value at 5–15 cm soil layer between the canopy. This was the area where roots from previous vegetation concentrated and was less disturbed during site preparation and planting of tree seedlings. Mineral-N content in the soil at stand age of 14 months was much reduced compared with that at 8 months old. However, the potential mineralisation of the two stand ages were the same. The rates at 20 months showed no improvement over the values at 14 months although an increment in the mineralisation rates was noted for the soil under the canopy. At 26 months, the potential nitrogen mineralisation rates have increased tremendously in the upper soil layers, particularly for soils under the canopy. In the first 5 cm soil layers under and between the tree canopy, mineral-N at 26 months exceeded the measurement at 8 months. A higher availability of litter could have intensified the activity of microorganisms (Wan Rasidah *et al.* 2001). The decomposition of litter influenced carbon availability in the soils and increased their mineralisation rate. Soil conditions under the canopy with abundance of litter could have generated a favourable environment for effective microbial activity. Overall measurements also showed that mineralised N remained mainly in the form of ammonium, which might indicate weak nitrification capacity in this soil.

Table 3 shows the average changes in the NO_3^--N concentration following one, two, three and four weeks of incubation period for the soils sampled at the four different stand ages studied. Even though differences in initial concentrations between soil profiles and between sampling locations were very big at 8 months (actual reading ranging from 11.85 to 98.76 mg kg^{-1} but not tabulated in this paper), the NO_3^--N concentration did not increase with time of incubation. This could not be attributed to the effect of denitrification because the soil was acidic and precautionary measures were taken during incubation. Under acidic soil condition, the activity of nitrifiers are reduced since the environment becomes rather toxic to them (Verstraete 1981a, b). At 14 and 20 months, there was also no clear increase in concentrations throughout the four weeks incubation period for all depths studied. However, the raw data showed that differences of NO_3^--N between depths were less distinct at 20 months probably due to the reduced mineral-N availability in the soil.

Table 2 Rate of nitrogen mineralisation in soil (mg kg^{-1} $week^{-1}$) at different depth and different stand ages

Soil depth (cm)	Location	NH_4^+-N				NO_3^--N				Total mineral-N			
		Age (month)				Age (month)				Age (month)			
		8	14	20	26	8	14	20	26	8	14	20	26
0–5	Under the canopy	7.00 a	3.86 a	3.82 b	9.75 a	1.16 a	- 0.37a	0.05 a	0.03 a	8.16 (1.60)	3.49 (0.90)	3.87 (0.57)	9.78 (1.54)
> 5–15		7.37 a	3.27 ab	4.90 a	7.25 b	1.13 a	- 0.82 a	0.00 a	0.00 a	8.50 (1.82)	2.45 (0.59)	4.90 (0.58)	7.25 (0.60)
> 15–30		7.32 a	3.16 ab	4.49 ab	5.56 b	- 0.50 a	- 0.62 a	0.20 a	0.11 a	6.82 (0.81)	2.54 (0.57)	4.69 (0.82)	5.67 (0.43)
> 30–45		4.58 b	2.65 b	4.11 ab	3.12 c	0.77 a	- 0.31 a	- 0.17 a	- 0.02 a	5.35 (0.59)	2.34 (0.83)	3.94 (0.76)	3.10 (0.41)
0–5	Between the canopy	7.88 b	4.74 a	3.17 c	8.20 a	- 0.12 b	- 0.42 a	- 0.37 a	- 0.05 a	7.76 (0.71)	4.32 (0.66)	2.80 (0.54)	8.15 (0.84)
> 5–15		7.96 a	5.24 a	3.42 b	3.66 b	2.61 b	- 0.36 a	- 0.34 a	0.14 a	10.57 (1.90)	4.88 (0.60)	3.08 (0.22)	3.80 (0.83)
> 15–30		4.93 c	4.38 a	4.13 a	2.40 b	4.00 a	- 0.27a	- 0.25 a	0.07 a	8.93 (1.58)	4.11 (0.74)	3.88 (0.47)	2.47 (0.51)
> 30–45		3.47 d	3.95 a	4.73 a	2.29 b	4.32 a	0.28 a	- 0.11 a	- 0.28 a	7.79 (0.74)	4.62 (0.80)	4.62 (0.42)	2.01 (0.29)

Means with the same letter for the four different depths are not significantly different at 5% probability level. Figures in parentheses are standard deviations calculated as $SD_{mineralisation} = \sqrt{(SD^2_{ammonium} + SD^2_{nitrate})}$

At stand age of 26 months, NO_3^--N concentration at initial stage had increased slightly compared with the previous measurement. The overall pattern did not show any clear change except for a small increase in the top 5-cm soil.

The distance between soil under and between the canopy was only about 1.5 m, yet the potential rate of mineralisation showed important differences (Table 2). At 8 months, the differences between the two locations were slight but the rates of mineralisation were high. When the stand reached 14 months old, the rate of mineralisation reduced tremendously, particularly for the soil under the canopy at lower depths. At 20 months old, some improvements were noted in the mineralisation rate for the soil taken under the canopy but the rates were further reduced for the soils between the canopy. A large increase in the mineralisation rate was observed at the 26-month-old stand for the soil under the canopy at 0–30 cm depth. A similar increase was also obtained for the soil between the canopy at 0–5 cm depth. These results indicated that within such a close distance and within the narrow soil layers, the activities of microorganisms were so diverse and dynamic.

Another factor that could have influenced nitrogen transformation in soil is the organic matter. Both macro- and microfauna organisms use organic matter in the soil as their source of energy and their activities influence the supply of mineral elements to plants (Stevenson 1994). Changes in this potential mineralisation corresponded with the fluctuation in the organic carbon content in the soil (Table 4). Higher organic carbon content at the

Table 3 Average increment in nitrate-N content in soil across the different incubation periods (one, two, three and four weeks) after the addition of 100 μg N as ammonium sulphate

Soil depth (cm)	Sampling location	Nitrate-N increment (mg kg^{-1}) *Stand age (months) ± SE 8	14	20	26
0–5	Under the canopy	- 2.74 ± 2.66	0.19 ± 0.42	0.43 ± 0.21	0.20 ± 0.56
> 5–15		- 0.80 ± 1.75	- 1.19 ± 0.86	- 0.40 ± 0.49	0.87 ± 0.32
> 15–30		0.75 ± 0.94	- 1.46 ± 0.72	- 0.40 ± 0.49	0.25 ± 0.46
> 30–45		2.13 ± 0.76	- 0.23 ± 0.21	- 0.47 ± 0.30	0.59 ± 0.17
0–5	Between the canopy	- 1.29 ± 1.98	- 0.28 ± 0.90	0.56 ± 0.30	0.81 ± 0.31
> 5–15		- 0.29 ± 0.69	- 1.30 ± 1.53	- 0.55 ± 0.36	0.41 ± 0.38
> 15–30		- 2.44 ± 1.91	- 0.45 ± 1.10	- 0.44 ± 0.28	0.31 ± 0.41
> 30–45		- 3.20 ± 1.04	- 0.22 ± 0.42	- 0.45 ± 0.18	- 0.23 ± 0.35

* SE – standard error

Table 4 The percentage of organic carbon in the soils under and between the canopy

Soil depth (cm)	Sampling location	Organic carbon (%) Stand age (month) 8	14	20	26
0–5	Under the canopy	1.77	1.22	1.51	1.80
> 5–15		1.12	0.60	0.87	1.52
> 15–30		0.64	0.48	0.53	0.95
> 30–45		0.46	0.33	0.40	0.68
0–5	Between the canopy	1.24	1.27	1.39	1.40
> 5–15		0.77	0.72	0.78	0.90
> 15–30		0.42	0.63	0.51	0.61
> 30–45		0.33	0.50	0.44	0.51

beginning came largely from roots that were not uprooted during site preparation. As time went by, these roots were mineralised and they gradually became less. Later on as the tree grew, more litter was produced (Wan Rasidah *et al.* 2001) and this resulted in an increase in organic matter in the top soil layers particularly those under the canopy. Substrate or organic carbon availability is among the main constraint for microbial activity within the soil (Holmes & Zak 1994). An increase in substrate availability can increase the microbial population if other factors such as temperature and moisture are not limiting.

In conclusion, this study has shown that mineralisation is an important nitrogen transformation pathway in this soil. The highest mineralisation rate measured was within the first 15-cm soil layer. On the other hand, there was no clear indication for potential nitrification.

References

HOLMES, W. E. & ZAK, D. R. 1994. Soil microbial biomass dynamics and net nitrogen mineralisation in northern hardwood ecosystems. *Soil Science Society American Journal* 58: 238–243.

KEENEY, D. R. 1980. Prediction of N availability in forest ecosystems: a literature review. *Forest Science* 26(1): 159–171.

MANGUIAT, I. J., MASCARINA, G. B., LADHA, J. K., BURESH, R. J. & TALLADA, J. 1994. Prediction of nitrogen availability and rice yield in lowland soils: nitrogen mineralisation parameters. *Plant and Soil* 160: 131–137.

MATSON, P. A. & VITOUSEK, P. M. 1981. Nitrogen mineralisation and nitrification potentials following clear-cutting in the Hoosier National Forest. *Forest Science* 27(4): 781–791.

STEVENSON, F. J. 1994. Pp. 14–16 and 96–112 in *Humus Chemistry: Genesis, Composition, Reactions.* Second edition. John Wiley & Sons Inc., New York.

VAN MIEGROET, H., HOMANN, P. S. & COLE, D. W. 1992. Soil nitrogen dynamics following harvesting and conversion of red alder and Douglas fir stands. *Soil Science Society American Journal* 56: 1311–1318.

VERSTRAETE, W. 1981a. Nitrification in agricultural systems: call for control. Pp. 565–572 in Clark, F. E. & Rosswall, T. (Eds.) *Terrestrial Nitrogen Cycles. Processes, Ecosystem Strategies and Management Impacts.* Ecological Bulletin 33. Stockholm.

VERSTRAETE, W. 1981b. Nitrification. Pp. 303–314 in Clark, F. E. & Rosswall, T. (Eds.) *Terrestrial Nitrogen Cycles. Processes, Ecosystem Strategies and Management Impacts.* Ecological Bulletin 33. Stockholm.

WAN RASIDAH, K., VAN CLEEMPUT, O. & ZAHARAH, A. R. 2001. Microbial respiration and nitrogen release patterns of decomposing *Acacia mangium* leaf litter from Kemasul Forest Reserve, Malaysia. *Journal of Tropical Forest Science* 13(1): 1–12.

WEIER, K. L. & MACRAE, I. C. 1993. Net mineralisation, net nitrification and potentially available nitrogen in the subsoil beneath a cultivated crop and a permanent pasture. *Journal of Soil Science* 44: 451–458.