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Studies on Nitrogen in Malaysian Soils. I. Native Fixed Ammonium Nitrogen

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Laboratory studies revealed the presence of native fixed ammonium nitrogen in the surface layer (0–30 cm) of all the twenty soils commonly found under rubber in Peninsular Malaysia. The amount varied from 10 p.p.m. (1.0% of total N) in Kulai series soil to as much as 429 p.p.m. (33.6% of total N) in Batu Anam series soil; this variation was found to be influenced by clay mineralogical composition of soil.

Except for Rengam series soil profile, there was a general increase in native fixed ammonium-N (in amount and as percentage total N) with depth in all the soil profiles (i.e. Durian, Batu Anam and Selangor series) under investigation. This caused a decline in the ratios of organic C to total N and organic C to organic N; the decline in the latter ratio being less. The differences in the values of the two ratios could be partly attributed to the variation in the levels of native fixed ammonium-N.

The presence of appreciable amounts of native fixed ammonium-N in temperate soils has been demonstrated by a number of researchers[1-7]. In addition to earlier work by Rodrigues[8], data on native fixed ammonium-N in tropical soils has been accumulating in recent years[9-14]. It was reported that a number of tropical soils contained substantial amounts of native fixed ammonium-N which may significantly contribute to the nitrogen economy in these soils.

There is no published information on native fixed ammonium-N in Malaysian soils. The present study investigates the importance of native fixed ammonium-N in these soils, particularly in relation to total N status and C/N ratios in the various pedogenetic horizons of four selected soil profiles.

EXPERIMENTAL

Soils

Twenty soil series commonly found under rubber in Peninsular Malaysia were selected. Their classification and the respective sampling locations are described in *Appendix A*. For each soil series, ten core samples of surface soil (0–30 cm depth) were taken from the interrow areas of rubber trees to minimise any fertiliser effects. The cores were bulked to form one composite sample per soil series. Samples from pedogenetic horizons of Durian, Batu Anam, Selangor and Rengam series were also collected from the respective soil profiles in the same sampling locations where the surface soil samples were collected. Descriptions and other details of these four soil profiles were as given by Chan[15].

Sample Preparation and Analytical Methods

All the soil samples were air dried and passed either through a 2 mm sieve (for pH, clay and cation-exchange capacity determination) or a 100 mesh sieve (for organic C, total N and native fixed ammonium-N analyses.) The pH was determined with a glass electrode (soil/water ratio, 1/2.5). Clay percentage was

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determined by the pipette method[16]. Cation-exchange capacity (CEC) was estimated by the ammonium acetate method[17]. Organic C was analysed by the wet combustion method of Allison[18]. Total N was determined by the Kjeldahl method while ammonium and nitrate-N were determined by steam distillation[19]. Native fixed ammonium-N was determined according to Procedure 'A' of Silva and Bremner[20] which was found to be relatively free from analytical defects[21]. All analyses were carried out in triplicate and the results (mean values) were expressed on oven-dry weight basis.

RESULTS AND DISCUSSION

Some physico-chemical as well as mineralogical properties of the twenty surface soils and soils in different pedogenetic horizons of the four soil profiles studied are shown in *Tables 1* and *2* respectively.

Native Fixed Ammonium-Nitrogen in Surface Soils

The amount of native fixed ammonium-N and their proportion to total N content in the surface soil (0–30) cm depth) of twenty soil series commonly found under rubber are shown in *Table 3.* The results indicate that all the surface soils investigated contained some native fixed ammonium-N. The amount of native fixed ammonium-N ranged from 9.5 p.p.m. in Kulai series soil to 428.5 p.p.m. in Batu Anam series soil *(Table 3).*

The range of native fixed ammonium-N in Malaysian soils was greater than the range of 4 p.p.m. to 98 p.p.m. in Nigerian soils[13] and 81 p.p.m. to 319 p.p.m. in Indian soils[11]. However, it was considerably smaller than the results reported for other tropical soils e.g. 0 p.p.m. to 585 p.p.m. in some Hawaiian soils[10] and 282 p.p.m. to 1920 p.p.m. in soils from the Carribbean region[8]. Except for the results published by Rodrigues[8], data on native fixed ammonium-N reported by other investigators were obtained by the method of Silva and Bremner[20] as employed in the present study. On this basis, therefore their results can reasonably be compared with the present data. The exceptionally high values and wide range of native fixed ammonium-N reported by Rodrigues[8] were possibly due to the decomposition of organic nitrogenous compounds to ammonium by the strong sulphuric acid and hydrofluoric acid treatment and the inclusion of released ammonium-N in the estimation of native fixed ammonium-N[21].

It is difficult to compare the present results with those reported for soils from temperate regions because of the differences in methods of determination. Nevertheless, it was found that some British soils contained between 52 p.p.m. and 252 p.p.m. of ammonium-N[1,2]. Several workers[3,5,6,7] reported a range of 9 p.p.m. to 432 p.p.m. in a variety of temperate North American soils. A comparatively wider range of 370 p.p.m. to 1070 p.p.m. was found by Magilevkina[27] for soils from the USSR.

When expressed as a proportion to total N content, the present results show native fixed ammonium-N accounted for 1.0% of total N in Kulai series soil to as much as 33.6% in Batu Anam series soil *(Table 3).* Generally, native fixed ammonium-N in more than half of the twenty surface soils under investigation did not contribute more than 3% of total N. In comparison, native fixed ammonium-N accounted for 1% to 7% of total N in the tropical surface soils of Nigeria[13]; 0.5% to 12% in

TABLE 1. SOME PHYSICO-CHEMICAL AND MINERALOGICAL PROPERTIES OF SURFACE SOILS

Soil series	pH (H_2O)	Clay (%)	CEC (me%)	Organic C (%)	Total N (p.p.m.)	Dominant clay mineral[a]
Durian	4.4	34	7.2	0.64	680	(K, I, Q, g)[b]
Serdang	4.6	14	3.4	0.68	590	(K, G, I)[b]
Harimau	4.9	22	4.4	0.69	900	(K, G)[c]
Ulu Tiram	4.9	26	4.2	0.72	680	(K, G)[c]
Kulai	4.6	39	5.4	0.76	1 000	(K, G)[c]
Jerangau	4.8	31	3.4	0.88	680	(K, g, G)[c]
Holyrood	4.6	31	4.8	0.99	1 160	(K, G, Q, I)[b]
Batu Anam	4.5	57	5.3	1.03	1 270	(K, I, Q)[d]
Lunas	4.8	33	5.6	1.39	1 200	(K, G, I)[c]
Segamat	4.7	66	9.4	1.45	1 560	(K, g)[b]
Bungor	4.4	33	5.6	1.46	1 090	(K, G)[c]
Kuantan	4.8	54	8.5	1.50	1 300	(K, G, g)[c]
Pohoi	4.8	43	7.5	1.55	1 200	(K, G)[c]
Sogomana	4.8	34	6.3	1.59	1 260	(K, I, Q, G)[e]
Sitiawan	4.6	53	5.6	1.62	1 290	(K, I, Q, G)e
Briah	4.4	45	12.4	1.75	1 530	(M, I, K)[f]
Malacca	4.6	44	8.2	1.80	1 440	(K, G, g)[c]
Rengam	4.4	52	5.5	1.87	1 400	(K, G, g)[g]
Munchong	4.7	57	7.8	1.92	1 480	(K, G, g, a)[b]
Selangor	4.2	48	23.3	3.48	2 550	(K, M, I)[b]

[a]K = Kaolin; G = gibbsite; g = goethite; I = illite; M = montmorillonite; Q = quartz

[b]After Yew[22]

[c]After Chan [15]

[d]After Mohd Noordin Daud[23]

[e]After Syed Sofi S. Omar[24]

[f]After Zainol Eusof[25]

[g]After Wong[26]

TABLE 2. SOME PHYSICO-CHEMICAL AND MINERALOGICAL PROPERTIES OF SOILS IN DIFFERENT PEDOGENETIC HORIZONS OF FOUR SOIL PROFILES

Soil series	Soil depth (cm)	pH (H_2O)	Clay (%)	CEC (me%)	Organic C (%)	Total N (p.p.m.)	Dominant clay mineral
Durian	0–8	4.5	37	9.3	1.66	1 320	K, I, Q
	8–38	4.4	46	8.5	0.52	560	K, I, Q
	38–48	4.4	45	14.1	0.33	450	K, I, Q
	48–117	4.5	55	12.0	0.14	420	K, I, Q
	117–140	4.5	57	13.6	0.11	270	K, I, Q
Batu Anam	0–15	4.4	51	6.5	1.47	1 500	K, I, Q
	15–46	4.3	61	5.6	0.26	840	K, I, Q
	46–84	4.3	65	4.6	0.20	770	K, I, Q
	84–137	4.4	61	2.5	0.13	810	K, I, Q
Selangor	0–23	4.0	27	22.0	3.62	3 120	K, M, I
	23–46	3.9	59	20.6	0.82	1 340	K, M, I
	46–61	3.2	58	25.8	0.92	1 080	K, M, I
	61–76	3.2	65	22.7	0.68	990	K, M, I
Rengam	0–13	4.3	42	6.7	1.69	1 630	K, G, g, Q
	13–81	4.4	54	2.9	0.48	490	K, G, g, Q
	81–152	4.3	52	2.3	0.14	260	K, G, g, Q

[a]Clay mineral data for Durian and Batu Anam series quoted from Chan[15] while those for Selangor and Rengam series quoted from Yew[22]

K = Kaolin; G = gibbsite; g = goethite; I = illite; M = montmorillonite; Q = quartz

Hawaiian soils[10] and 6% to 55% in Indian soils[11].

It is normally accepted that the presence of fixed ammonium-N in soil is the result of 'trapping' of ammonium ions in the structure of certain clay minerals. Clay mineral such as illite, montmorillonite and vermiculite have higher ammonium fixing capacity than clay minerals with unexpandable inter-layer lattice structure such as kaolinite, gibbsite and goethite[5,28]. Variation in the levels of native fixed ammonium-N in soils from the various parts of the world is apparently due to differences in their inherent clay mineralogical composition.

TABLE 3. NATIVE FIXED AMMONIUM-NITROGEN CONTENTS IN SURFACE SOILS

Soil series	Native fixed ammonium-N (p.p.m.)	Native fixed ammonium-N (% of total N)
Durian	60.3	9.4
Serdang	26.5	4.6
Harimau	18.9	2.0
Ulu Tiram	15.4	2.2
Kulai	9.5	1.0
Jerangau	18.8	2.7
Holyrood	19.7	1.7
Batu Anam	428.5	33.6
Lunas	17.5	1.4
Segamat	22.3	1.4
Bungor	21.2	1.9
Kuantan	22.2	1.7
Pohoi	45.3	3.7
Sogomana	39.3	3.1
Sitiawan	82.0	6.4
Briah	126.4	11.1
Malacca	33.5	2.2
Rengam	17.5	1.3
Munchong	15.5	1.1
Selangor	148.6	5.2

In the surface samples of twenty soil series commonly found under rubber the types of predominant clay minerals were also very variable *(Table 1)* and could similarly account for their differences in the native fixed ammonium-N contents. Relatively low native fixed ammonium-N content was found in most of the soils where kaolin, gibbsite and goethite was the predominant clay mineral. In contrast, in soils such as Durian, Batu Anam, Sitiawan, Briah and Selangor series, where illite and/or montmorillonite were also present, comparatively higher amounts of native fixed ammonium-N was found *(Table 3)*.

Profile Distribution of Native Fixed Ammonium-Nitrogen and its Influence on Carbon/Nitrogen Ratios

Native fixed ammonium-N contents and C/N ratios of soils in different predogenetic horizons in the profiles of Durian, Batu Anam, Selangor and Rengam series are shown in *Table 4*.

The results show that native fixed ammonium-N level increased significantly with depth in the profiles of Batu Anam and Selangor series, slightly in Durian series but remained the same in Rengam series. Similar observations of increasing native fixed ammonium-N with depth

TABLE 4. NATIVE FIXED AMMONIUM-NITROGEN AND CARBON/NITROGEN RATIOS OF SOILS IN DIFFERENT PEDOGENETIC HORIZONS OF FOUR SOIL PROFILES

Soil series	Soil depth (cm)	Native fixed ammonium-N (p.p.m.)	Native fixed ammonium-N (% of total N)	Organic C / Total N	Organic C / Organic N[a]
Durian	0–8	69	5	13	13
	8–38	54	10	10	10
	38–48	71	16	7	9
	48–117	75	18	3	4
	117–140	72	27	4	5
Batu Anam	0–15	437	29	10	14
	15–46	468	56	3	7
	46–84	500	65	3	8
	84–137	599	74	2	6
Selangor	0–23	114	4	12	12
	23–46	138	10	6	7
	46–61	143	13	9	10
	61–76	144	14	7	8
Rengam	0–13	13	0.8	11	11
	13–81	15	4	10	10
	81–152	13	5	6	6

[a]Organic N = Total N – Native fixed ammonium-N

were made for most soil profiles in tropical regions[8,9,12,13]. An exception was observed in some Hawaiian soils derived from volcanic ash and basalt where the concentration of native fixed ammonium-N was found to decrease with depth of soil profiles[10].

The proportion of native fixed ammonium-N to total N, (expressed as percentage) however, increased with depth in all the four soil profiles examined *(Table 4)*. This observation again agreed with the findings of other workers[8,9,12,13] but differed from the results of Mikami and Kanehiro[10].

The value of native fixed ammonium-N (expressed either as the amount or as percentage of total N) in all the horizons was largest in Batu Anam profile, smallest in Rengam profile and in between in

Durian and Selangor profiles *(Table 4)*. As already indicated, this could possibly be the reflection of the differences in clay mineralogical composition of the soils *(Table 2)*.

Generally, in all the four soils studied, organic C, total N and organic C/total N ratio decreased with increasing soil depth *(Tables 2* and *4)*. The decreasing organic C and total N contents are usually attributed to lower levels of soil organic matter (or humus) at lower depths. The rather drastic narrowing of the organic C/total N ratio with depth was found to be influenced by the presence of native fixed ammonium-N[4,7,9].

Organic N, which was calculated from the difference between total N and native fixed ammonium-N, was used to estimate organic C/organic N ratio. The relationships between organic C/total N and organic C/organic N ratios as given in *Table 4* show that the latter was slightly higher in all except the Rengam series soil profile. Furthermore, the results also indicate similar decrease with depth of organic C/organic N ratio but its decrease was less marked as compared with the organic C/total N ratio. The present results of less drastic narrowing of organic C/organic N ratio with depth, particularly in Batu Anam and Selangor series soil profiles, confirm earlier reports for other tropical soils[8,9,12,14] and it was presumably associated with the presence of significant amounts of native fixed ammonium-N *(Table 4)*. On the other hand, while both ratios decreased with depth in all the three profiles no difference was observed in their values in Rengam series profile. Similar observation was made for some Hawaiian soils of volcanic ash origin[10] and it was suggested to be due to the presence of very small amount of native fixed ammonium-N.

CONCLUSION

The present results show that the surface depth (0–30 cm) in most of the twenty soil series commonly found under rubber contained only a small amount of native fixed ammonium-N. In a few soils such as Batu Anam series, however, native fixed ammonium-N accounted for a very significant portion of total N. Since the availability of native fixed ammonium-N to crops is not fully known, further work should be carried out to determine its agronomic significance in the nitrogen nutrition of rubber growing on such soils with high native fixed ammonium-N content.

The declining ratios of organic C/total N and organic C/organic N with soil depth could be partly attributed to the increasing amounts of native fixed ammonium-N in the lower soil horizons. Additionally, the amount of native fixed ammonium-N significantly influenced the two ratios.

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REFERENCES

1. BREMNER, J.M. (1959) Determination of Fixed Ammonium in Soil. *J. Agric. Sci.*, **52**, 147.

2. BREMNER, J.M. AND HARADA, T. (1959) Release of Ammonium and Organic Matter from Soil by Hydrofluoric Acid and Effect of Hydrofluoric Acid Treatment on Extraction of Soil Organic Matter by Neutral and Alkaline Reagents. *J. Agric. Sci.*, **52**, 137.

3. HANWAY, J.J. AND SCOTT, A.D. (1956) Ammonium Fixation and Release in Certain Iowa Soils. *Soil Sci.*, **82**, 379.

4. STEVENSON, F.J. (1959) Carbon-nitrogen Relationships in Soils. *Soil Sci.*, **88**, 201.

5. STEVENSON, F.J. AND DHARIWAL, A.P.S. (1959) Distribution of Fixed Ammonium in Soils. *Soil Soc. Am. Proc.*, **23**, 121.

6. WALSH, L.N. AND MURDOCK, J.K. (1960) Recover of Fixed Ammoniaby Corn in Greenhouse Studies. *Soil Sci. Soc. Am. Proc.*, **27**, 200.

7. YOUNG, J.L. (1962) Inorganic Soil Nitrogen and Carbon: Nitrogen Ratios of Some Pacific Northwest Soils. *Soil Sci.*, **93**, 397.

8. RODRIGUES, G. (1954) Fixed Ammonia in Tropical Soils. *J. Soil Sci.*, **5**, 264.

9. MOORE, A.W. AND AYEKE, C.A. (1965) HF-extractable Ammonium Nitrogen in Four Nigerian Soils. *Soil Sci.*, **99**, 335.

10. MIKANI, D.T. AND KANEHIRO, Y. (1968) Native Fixed Ammonium in Hawaii Soils. *Soil Sci. Soc. Am. Proc.*, **32**, 481.

11. RAJU, G.S.N. AND MUKHOPADHYAY, A.M.K. (1973) Distribution of Native Fixed Ammonium and Other Forms of Nitrogen in Different Soils of West Bengal. *J. Indian Soc. Soil Sci.*, **21**, 257.

12. SAID, N.B. (1973) Ammonium Fixation in the Sudan Cazira Soils. *Pl. Soil*, **38**, 9.

13. OPUWARIBO, E. AND ODU, C.T.I. (1974) Fixed Ammonium in Nigerian Soils. I. Selection of Method and Amounts of Native Fixed Ammonium. *J. Soil Sci.*, **25**, 256.

14. DALAL, R.C. (1977) Fixed Ammonium and Carbon-nitrogen Ratios of Some Trinidad Soils. *Soil Sci.*, **124**, 323.

15. CHAN, H.Y. (1975) Soil Taxonomy and Soils under *Hevea* in Peninsular Malaysia. Master of Science thesis, Cornell University, United States of America.

16. PIPER, C.S. (1950) *Soil and Plant Analysis.* Australia: University of Adelaide.

17. METSON, A.J. (1956) Methods of Chemical Analysis for Soil Survey Samples. *DSIR Soil Bur. (N.Z.) Bull. No. 12.*

18. ALLISON, L.B. (1960)· Wet Combustion Apparatus and Procedure for Organic and Inorganic Carbon in Soils. *Soil Sci. Soc. Am. Proc.*, **24**, 36.

19. BREMNER, J.M. (1965) Inorganic Forms of Nitrogen. *Methods of Soil Analysis (Black, C.A., ed)*, Part 2, pp.1179–1232. Madison, Wisconsin: AN. Soc. Agronomy.

20. SILVA, J.A. AND BREMNER, J.N. (1966) Determination and Isotoperatio Analysis of Different Forms of Nitrogen in Soils. 5 Fixed Ammonium. *Soil Sci. Soc. Am. Proc.*, **30**, 587.

21. BREMNER, J.M. NELSON, D.A. AND SILVA, J.A. (1967) Comparison and Evaluation of Methods of Determining Fixed Ammonium in Soils. *Soil Sci. Soc. Am. Proc.*, **31**, 462.

22. YEN, F.K. (1977) Characterisation of Some Peninsular Malaysian Soils Emphasis on their Potassium Supplying Power. Master of Science thesis, State University of Ghent, Belgium.

23. MOHD NOORDIN DAUD (1975) Pedological Study of Some Shale Derived Soils of Peninsular Malaysia. Master of Science thesis, State University of Ghent, Belgium.

24. SYED SOFI S. OMAR (1976) A Comparatives Study of Some Soils Derived from Alluvium from the West and East Coast of Peninsular Malaysia. Master of Science thesis, State University of Ghent, Belgium.

25. ZAINOL EUSOF (1977) A Study of Some Acid Sulphate Soils from the West Coast of Peninsular Malaysia. Master of Science thesis, State University of Ghent, Belgium.

26. WONG, C.B. (1976) A Study of Deep Weathering Profile and a Toposequence on Granite in Peninsular Malaysia. Master of Science thesis, State University of Ghent, Belgium.

27. MAGILEV KINA, I.A. (1964) Fixation of Ammonium in the Soil and the Method of Determining it. *Soviet Soil Sci. No. 2,* 185.

28. NOMMIK, H. (1965) Ammonium Fixation and Other Reactions Involving a Non-enzymatic Immobilisation of Mineral Nitrogen in Soil. *Soil Nitrogen, (Bartholomew, W.V. and Clark, F.C. ed),* Chap. 5, pp. 198–258. Madison, Wisconsin: Am. Soc., Agronomy.

APPENDIX A

CLASSIFICATION AND SAMPLING SITES OF THE SOILS STUDIED

Soil series	Soil order[a]	Parent material	Sampling location
Durian	Ultisol	Siliceous shale	Near Department of Agriculture Research Station, Ayer Itam, Johore
Serdang	Ultisol	Sandstone	RRIM Experiment Station, Sungei Buloh, Selangor
Harimau	Ultisol	Older alluvium	Sungei Tiram Estate, Johore
Ulu Tiram	Inceptisol	Older alluvium	Sungei Tiram Felda Scheme, Johore
Kulai	Ultisol	Polyolite	Kulai Besar Estate, Johore
Jerangau	Ultisol	Granodiorite	Melaka Pindah Estate, Malacca
Holyrood	Inceptisol	Sub-recent riverine	Sungei Bruas Estate, Perak
Batu Anam	Inceptisol	Shale	Near Department of Agriculture Research Station, Ayer Itam, Johore
Lunas	Inceptisol	Sub-recent riverine alluvium	Wellesley Lunas Estate, Province Wellesley
Segamat	Oxisol	Andesite	Sungei Muar Estate, Johore
Bungor	Ultisol	Quartzite/shale	RRIM Station, Kota Tinggi, Johore
Kuantan	Oxisol	Basalt	Kuala Reman Estate, Kuantan, Pahang
Pohoi	Ultisol	Carbonaceous shale	RRIM Station, Kota Tinggi, Johore
Sogomana	Inceptisol	Sub-recent riverine alluvium	Cashwood Estate, Perak
Sitiawan	Inceptisol	Sub-recent riverine alluvium	Sogomana Estate, Perak
Briah	Entisol	Mixed riverine and marine alluvium	Sungei Rambai Estate, Selangor
Malacca	Oxisol	Argillaceous shale	Cheng Estate, Malacca
Rengam	Ultisol	Granite	RRIM Experiment Station, Sungei Buloh, Selangor
Munchong	Oxisol	Argillaceous	RRIM Experiment Station, Sungei Buloh, Selangor
Selangor	Inceptisol	Marine alluvium	Sungei Rambai Estate, Selangor

[a]Soil classified by Chan[15] according to the Seventh Approximation, United States Department of Agriculture.