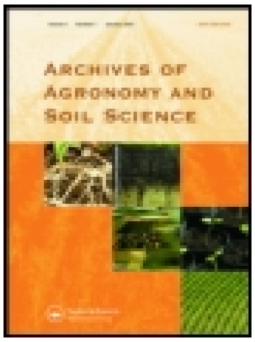

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Archives of Agronomy and Soil Science

ISSN: 0365-0340 (Print) 1476-3567 (Online) Journal homepage: https://www.tandfonline.com/loi/gags20

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Archives of Agronomy and Soil Science
December 2006; 52(6): 687 – 695

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(Einfluss der Einbringung von Niemblättern und Geflügeldung auf die Nährstoffdynamik eines Haplic Acrisol)

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(Received 31 October 2005; accepted 2 October 2006)

Abstract
A 12-week incubation study of a Haplic Acrisol amended with ground neem leaves (*Azadirachta indica* Adr. Juss.) (20, 40, 60, 80 and 100 t h^{-1}) plus 10 t h^{-1} poultry manure in pots were carried out at the Technology Village of the University of Cape Coast, Ghana, to assess the changing patterns of NH_4^+—N, NO_3^-—N and available P. The study lasted for 12 weeks starting from 17 April 2004. The peak of release of NH_4^+—N occurred at the 2nd week after incubation of samples; the peak of release of the available P occurred also at the 2nd week and the NO_3^-—N occurred at the 4th week. The production of NH_4^+—N and available P had proportional relationships with the quantity of neem leaves and poultry manure incorporated into the soil. The amount of NO_3^-—N produced was not proportional to the quantity of the neem leaves and the poultry manure as above. The higher levels of the neem leaves (100 t, 80 t and 60 t) plus the poultry manure produced lower cumulative values of NO_3^-—N than the lower levels (40 t and 20 t) of the neem leaves plus the poultry manure. This exception was assigned to the probable nitrification inhibitory role played by the active ingredient (azadirachtin) in the neem leaves which was expected to increase with the increasing levels of the neem leaves. The poultry manure was found to enhance the release of NH_4^+—N, NO_3^-—N and available P in the neem leave-poultry manure soil amendment. The moisture content of treatments significantly increased in relation to the amount of neem leaves and poultry manure in the amendment.

Keywords: *Neem leaves, poultry manure, soil amendment, nitrification inhibition*

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ISSN 0365-0340 print/ISSN 1476-3567 online © 2006 Taylor & Francis
DOI: 10.1080/03650340601044172

Introduction

The maintenance of adequate levels of soil nutrients plays a key role in sustaining crop yield. In order to maintain adequate levels of soil nutrients farmers apply both organic and inorganic fertilizers. More attention is being focused on the use organic fertilizers, as they are more environmentally friendly than inorganic fertilizers.

Neem products (*Azadirachta indica* Adr. Juss.) have received much attention as organic fertilizers. They have been demonstrated to contain more nitrogen, phosphorus, potassium, calcium, and magnesium than farmyard manure or sewage sludge and are widely used in India to fertilize cash crops, particularly sugarcane and vegetables (Board on Science and Technology for International Development [BOSTID] 1992).

Used as organic manure, neem cake has been credited with a 37% increase in cotton yields, 19% in paddy, and has proved superior to castor, mahua or cow dung as a fertilizer for sugarcane (Food and Agriculture Organization [FAO] 1980). Blended with urea, neem cake has significantly reduced the cost of nitrogen fertilizer while at the same time achieving considerable yield improvement (FAO 1980). Several other studies have shown the ability of neem products (seeds and leaves) to provide soil nutrients for crop development (Reddy et al. 1993; Khan & Saxena 1997; Akhtar 1999; Chakrabarti 2000).

Reddy et al. (1993) effectively used 50 g neem leaves/kg (100 t h^{-1}) soil to control root-knot nematodes on papaya and to improve the nutrient status of the amended soil, however, the changing trends of nutrients with time was not studied. Literature on the changing trends of nutrients with time as neem products are incorporated in soil as a whole is sparse.

The present study therefore looked at the dynamics of NH_4^+—N, NO_3^-—N and available P of a Haplic Acrisol amended with neem leaves and poultry manure. Poultry manure is known to be an effective nutrient provider (Abdel Magid et al. 1995; Riegel et al. 1996; Nyakatawa & Reddy 2000) and its addition to the neem leaves was to assess its influence in the amendment.

Materials and methods

The experiment was conducted at the Technology Village of the University of Cape Coast, Ghana (5.07°N, 1.14°W). The soil of the site belongs to the Benya Series, classified as a Haplic Acrisol (FAO/UNESCO 1988), a sandy loam with a soil pH of 5.12. A composite top-soil (0 – 15 cm) was collected from the site. The collected soil was used for treatment preparation the following day at mean moisture content of 5.40%. The soil was sieved through a 2 mm sieve.

Neem leaves were harvested around the experimental site, air-dried for one week and ground to pass through a 2 mm sieve. The poultry manure was collected from the University of Cape Coast Research Farm, air dried for three weeks and also passed through a 2 mm sieve. Organic carbon in the neem leaves and the poultry manure was determined by the Walkley-Black method (International Institute of Tropical Agriculture [IITA] 1985). Kjeldahl oxidation method was used to determine the total N and the total P was determined Colorimetrically with digested samples (Anderson & Ingram 1989). Total K was determined from digested samples using a Flame Photometer (IITA 1985) (Table I).

The soil, neem leaves and poultry manure were thoroughly mixed in combinations as shown in Table II. Treatments were placed in plastic pots with perforations at the bottom, having a carrying capacity of 3 kg of soil. The treatments were replicated three times. Each replicate consisted of a batch of ten of the pots. The replicates were randomly placed on the

Table I. Total nitrogen, phosphorus, potassium and carbon content of the neem leaves and poultry manure.

	N (%)	P (%)	K (%)	OC (%)	C:N	Moisture Content (%)
Poultry manure	3.55	1.29	0.95	36.97	10.41	18.77
Neem leaves	2.50	0.14	1.19	49.46	19.78	16.05

Table II. Treatment combinations and description.

	Treatment h^{-1}	Description
T_1	Control	Unamended soil (No addition of neem leaves or poultry manure)
T_2	10 t PM	10 tons of poultry manure
T_3	20 t NL	20 tons of neem leaves
T_4	20 t NL + 10 t PM	20 tons of neem leaves plus 10 tons of poultry manure
T_5	40 t NL + 10 t PM	40 tons of neem leaves plus 10 tons of poultry manure
T_6	60 t NL + 10 t PM	60 tons of neem leaves plus 10 tons of poultry manure
T_7	80 t NL + 10 t PM	80 tons of neem leaves plus 10 tons of poultry manure
T_8	100 t NL + 10 t PM	100 tons of neem leaves plus 10 tons of poultry manure

field in April 2004. Treatments were occasionally stirred and weeds removed. No water was artificially added to the treatments. There was natural frequent rainfall throughout the experimental period.

Sampling was immediately conducted after placement of treatments on the field for ammonium-N, nitrate-N and available P determination. Further sampling was done after 2, 4, 6, 8, 10 and 12 weeks of incubation of treatments. During sampling one pot per replicate was picked as a representative sample.

The ammonium-N and nitrate-N were determined after extraction of 40 g sample with 2 M KCl followed by steam distillation with MgO and Devarda's Alloy respectively. Distillates were titrated with 0.01 M HCl (Rowel 1994). Available phosphorus was determined through the ascorbic acid method after extraction of 1 g sample with Bray No. 1 solution (IITA 1985).

The data were subjected to analysis of variance (ANOVA) and the Duncan's Multiple Range Test ($p \leq 0.05$) for the separation of means using the MSTAT-C statistical software package (Freed 1992).

Results and discussions

C:N ratios of neem leaves and poultry manure

A C:N ratio of organic manure greater than 30:1 will likely immobilize N if applied to soil, while those with low C:N ratios less than 20:1 will mineralize organic N to inorganic (plant-available) N (Tisdale et al. 1993). Mineralization of N is generally rapid from plant residues with a low C:N ratio (Fox et al. 1990) because N is in excess of the requirements for microbial growth. Nitrogen in plant residue with a high C:N ratio is retained by the microbial biomass (Ocio et al. 1991) and only slowly released. Based on these assumptions the C:N ratios of the treatments (Table I) were expected to favour mineralization of organic N with the poultry manure having a lower C:N than the neem leaves been the more favored when applied to the soil.

Ammonium nitrogen

Figure 1 represents the Ammonium nitrogen (NH_4^+—N) produced from the control (unamended soil) and soil amended with neem leaves and poultry manure as affected by incubation period. Two conspicuous peaks of NH_4^+—N production were observed, the highest peak occurred at the 2nd week for the neem amended soil and the initial time of analysis (0 week) for the solely poultry manure amended soil. The NH_4^+—N production dropped between the 4th and the 6th week and rose to the lowest peak at the 8th week of incubation. By the 10th week the NH_4^+—N was almost negligible.

Van Kessel et al. (2000) worked on soil treated with materials such as, urea, trypticase, forages and soybean meal and found the maximum peak of NH_4^+—N production to occur between the 2nd and the 7th day of incubation with depletion of production setting in between the 14th (2nd week) and the 28th (4th week) day of incubation. In the current study the NH_4^+—N production also dropped by the 4th week of incubation as in the case of Van Kessel et al. (2000), however, the different peaks of NH_4^+—N production observed between the two experiments might be the differences in the time of NH_4^+—N analysed. The second slight peak of NH_4^+—N production detected at the 8th week of incubation could be attributed to the high water content of samples (Figure 4), which might have created anaerobic

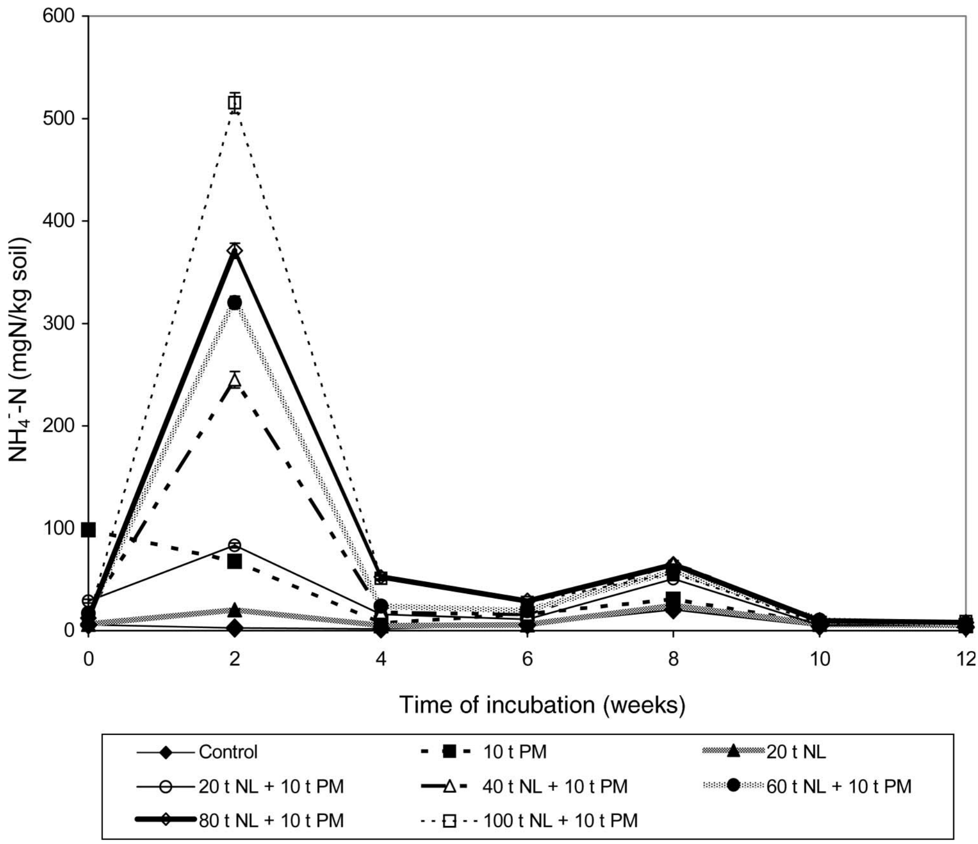

Figure 1. Changes in NH_4^+ nitrogen released in unamended soil and soil amended with neem leaves and poultry manure as affected by incubation period (bars are standard errors).

conditions favouring immobilization of NO_3^-—N to NH_4^+—N and ammonification of organic nitrogen (Mahimairaja et al. 1994).

The quantity of neem leaves plus the poultry manure in the amendment seemed to be related proportionally to the amount of cumulative NH_4^+—N produced, however, the production of the NH_4^+—N was likely determined by the poultry manure. This is shown where the cumulative NH_4^+—N production of the 20 t NL (T_3) treatment nearly tripled with the addition of poultry manure, that is for the 20 t NL + 10 t PM (T_4) treatment (Table III). This observation might be expected as the poultry manure has higher percentage of N and a smaller C:N than the neem leaves (Table I) and also contains easily decomposable compounds (Abdel Magid et al. 1995) and high levels of microbes to speed up mineralization (Bacharach 1957).

Nitrate nitrogen

Figure 2 indicates the Nitrate nitrogen (NO_3^-—N) produced from the treatments. Two peaks of NO_3^-—N production were also observed as in the case of NH_4^+—N. The major peak of NO_3^-—N production was recorded at the 4th week of incubation and a minor one at the 10th week of incubation. The solely poultry manure treatment and the control had their major peaks of NO_3^-—N production at the 2nd week of incubation. All the amended soil had higher levels of NO_3^-—N production than the control. The peak of NO_3^-—N release (Figure 2) was detected 2 weeks after those of NH_4^+—N release (Figure 1). As the production of NH_4^+—N declined the production of NO_3^-—N went up. Such trends of NH_4^+—N production peaks giving way to NO_3^-—N production peaks (Van Kessel et al. 2000) are bound to happen in an incubation process as NH_4^+—N production is a prerequisite for the production of NO_3^-—N. The high moisture content of samples measured between the 6th and 10th week of incubation (Figure 4) might have caused the reduction of the NO_3^-—N in samples at this stage (Figure 2) through denitrification.

The extent of the NO_3^-—N curves (Figure 2) and the cumulative values of the NO_3^-—N were not bearing proportional relationships with the quantity of neem leaves in the treatment. The lower levels of the neem leaves (20 t and 40 t) plus the poultry manure produced significantly higher cumulative NO_3^-—N than the treatments with the higher levels (100 t, 80 t and 60 t) of the neem leaves (Table III). Neem products such as the seed powder and the seed cake have been reported to be nitrification inhibitors because of azadirachtin, the active

Table III. Cumulative concentrations of NH_4^+—N, NO_3^-—N and available phosphorus in the treatment after 12 weeks of incubation.

	Treatment h^{-1}	NH_4^+—N (mg/kg soil)	NO_3^-—N (mg/kg soil)	Available phosphorus (mg/kg soil)	Moisture (%)
T_1	Control	44.62 h	92.27 e	44.50 f	65.08 h
T_2	10 t PM	233.16 e	367.25 c	258.83 e	73.52 g
T_3	20 t NL	74.06 g	230.04 d	49.57 f	78.81 f
T_4	20 t NL + 10 t PM	200.79 f	636.92 a	284.45 d	92.72 e
T_5	40 t NL + 10 t PM	378.73 d	655.27 a	295.41 c	97.15 d
T_6	60 t NL + 10 t PM	456.65 c	406.74 b	331.59 b	112.09 c
T_7	80 t NL + 10 t PM	547.38 b	390.94 b	356.81 a	119.05 b
T_8	100 t NL + 10 t PM	678.20 a	408.13 b	351.86 a	130.04 a
		LSD = 6.98	LSD = 20.72	LSD = 8.06	LSD = 2.36

Means within columns with the same letters are not significantly different ($p \leq 0.05$).

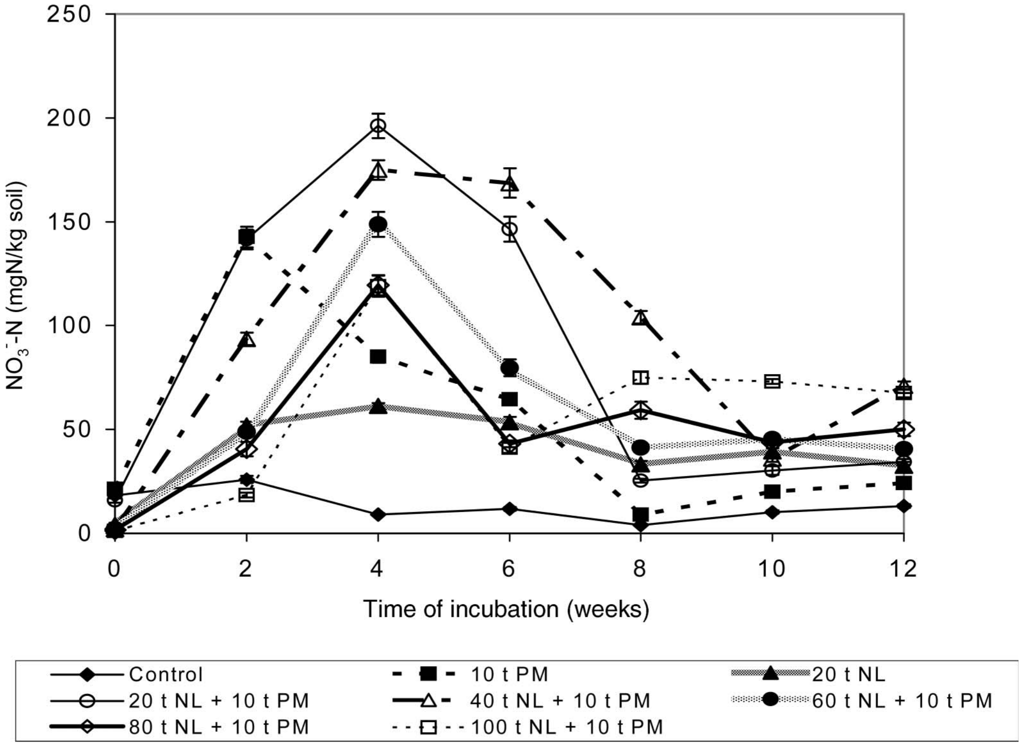

Figure 2. Changes in NO_3^- nitrogen in unamended soil and soil amended with neem leaves and poultry manure as affected by incubation period (bars are standard errors).

ingredient of the neem plant (Neem Foundation 1997; Lalljee et al. 1999; Deepanjan et al. 2000; Shah & Faheem 2000). The higher levels of neem leaf with corresponding high amounts of azadirachtin might have played a similar nitrification inhibitory role in the present study.

As in the case of NH_4^+—N production the addition of the poultry manure to the neem leaves might have enhanced the release of the NO_3^-—N in the treatments. This is revealed in the cumulative values of NO_3^-—N for the 20 t NL (T_3) treatment (230.04 mg/kg soil) and the 20 t NL + 10 t PM (T_4) treatment (636.92 mg/kg soil). The addition of the poultry manure to the 20 t neem leaves in the treatment almost tripled the value as compared to the solely neem leaves in the treatment.

Available phosphorus (P)

The changes of available P in the treatments as affected by the incubation of treatments are portrayed in Figure 3. One conspicuous peak of available P production was observed at the 2nd week of incubation for all the treatments except the control and the solely 20 t NL (T_3) which remained almost flat throughout the incubation period. The levels of the curves were seen to bear some proportional relationship with the quantity of neem in the treatment.

Table III represents the cumulative amount of available P throughout the incubation period for the treatments. The 100 t NL + 10 t PM (T_8) and the 80 t NL + 10 t PM (T_7) gave

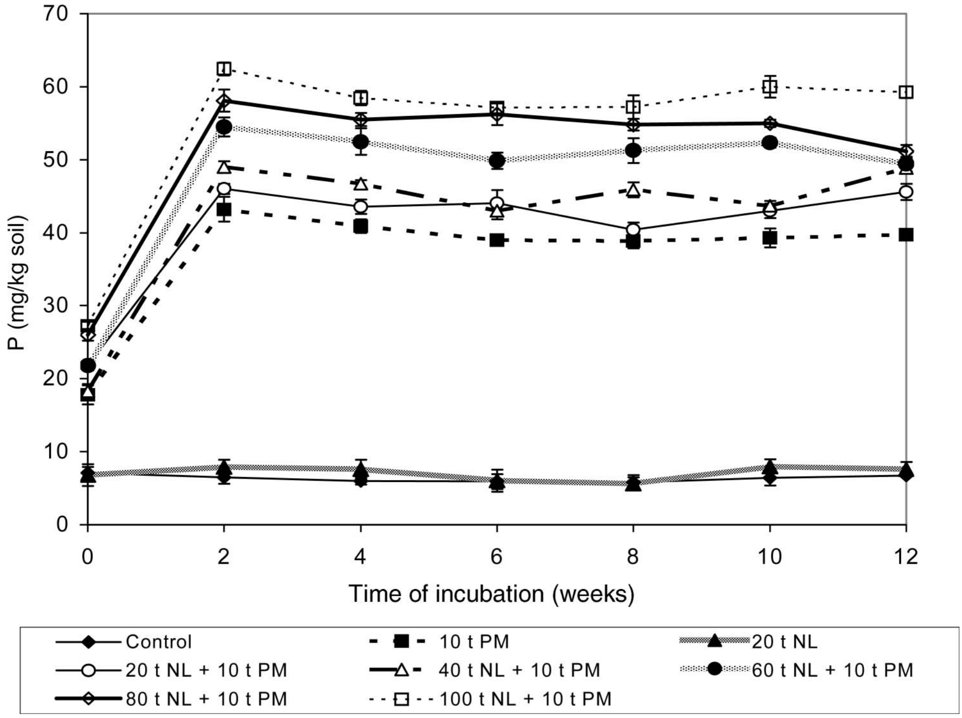

Figure 3. Changes in available phosphorus in unamended soil and soil amended with neem leaves and poultry manure as affected by incubation period (bars are standard errors).

cumulative values of 351.86 mg/kg soil and 356.81 mg/kg soil respectively which were not significantly different from each other, the highest among the treatments. The rest of the cumulative values in order of magnitude were 331.59, 295.41, 284.45, 258.83, 49.57 and 44.50 mg/kg soil for 60 t NL + 10 t PM (T_6), 40 t NL + 10 t PM (T_5), 20 t NL + 10 t PM (T_4), 10 t PM (T_2), 20 t NL (T_3) and control treatments respectively. The 20 t NL (T_3) was not significantly different from the control. The 20 t NL + 10 t PM (T_4) gave a cumulative of 284.45 mg/kg soil available P which was almost 6 times that of the 20 t NL (T_3) treatment.

Similar to the above discussions the poultry manure seemed to have dictated and enhanced the release of available P in the treatments. The addition of the poultry manure boosted the release of available P because the poultry manure has far higher content of total phosphorus than the neem leaves (Table I) and high levels of microbes to speed up mineralization (Bacharach 1957).

Moisture content of amended soil

The moisture content of the amended soil increased with the increasing levels of amendment (Figure 4). All the amendments had higher moisture content above the control/unamended soil. The incorporation of the neem leaves and the poultry manure significantly increased the water holding status of the soil (Table III). Similar results have been recorded (Kalburtji et al. 1997; Wong et al. 1999).

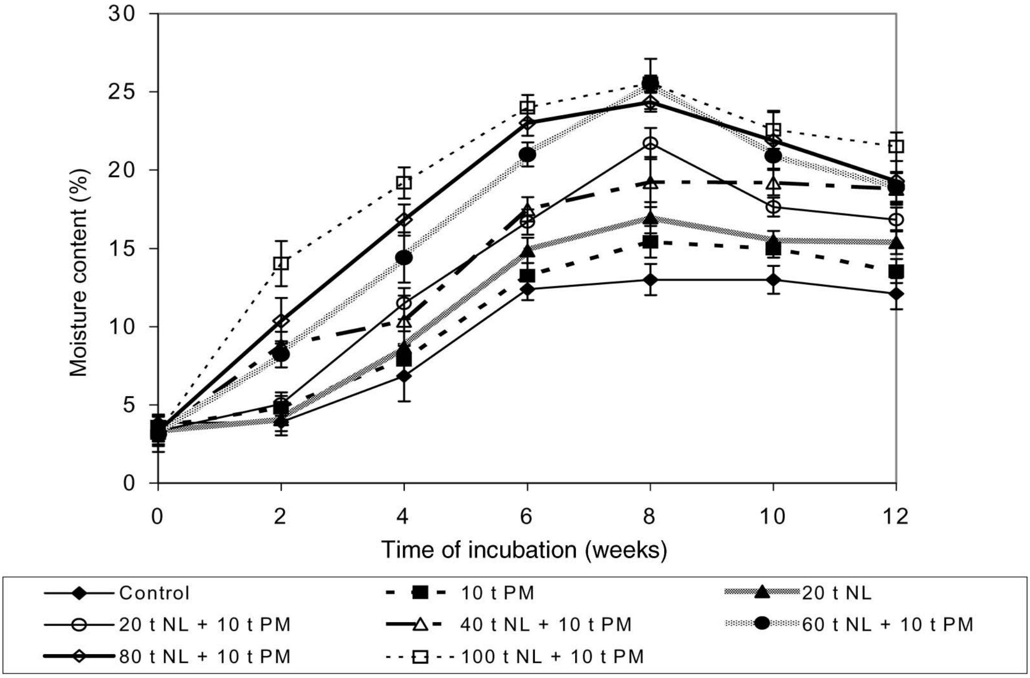

Figure 4. Moisture content of samples at periods of analysis (bars are standard errors).

Conclusions

Soil nutritional levels increased with increasing levels of the neem leaves and the poultry manure incorporation in the soil. The peak of production of NH_4^+—N occurred at the 2nd week, the NO_3^-—N occurred at the 4th week, 2 weeks after that of NH_4^+—N, and the available P occurred at the 2nd week of sample incorporation in the soil. The production of NH_4^+—N and available P increased with the rise in levels of the neem leaves in the amendment. The production of NO_3^-—N, however, did not follow this pattern, and this was attributed to the probable nitrification inhibitory role played by azadirachtin in the neem leaves. The poultry manure was found to boost and enhance the release of nutrients in the soil.

The incorporation of the neem leaves and the poultry manure significantly increased the moisture content of the soil; the moisture content had a proportional relationship with the quantity of organic manure.

As an alternative to the use of inorganic fertilizers, neem leaves and poultry manure could be used as soil amendments to improve the nutrient status of soils for crop production.

Acknowledgements

We thank the Centre for School and Community Science and Technology Studies (SACOST), University of Education, Winneba, Ghana, for supporting this project financially.

References

Abdel Magid HM, Abdel Aal SI, Rabie RK, Sabrah REA. 1995. Chicken manure as a biofertilizer for wheat in the sandy soils of Saudi Arabia. J Arid Environ 29:413–420.

Akhtar M. 1999. Plant growth and nematode dynamics in response to soil amendments with neem products, urea and compost. Biores Technol 69:181 – 183.

Anderson JM, Ingram JSI. 1989. Tropical soil biology and fertility: A handbook of methods. Wallingford, UK: CAB International.

Bacharach U. 1957. The aerobic breakdown of uric acid by certain *Pseudomonas*. J Gen Microbiol 17:1 – 9.

Board on Science and Technology for International Development (BOSTID). 1992. Neem: A tree for solving global problems. Document text, 6th ed. Humanity Development Library.

Chakrabarti S. 2000. An integrated approach to managing rice stem nematodes. Int Rice Res Notes 25:16 – 17.

Deepanjan M, Sushil K, Pathak H, Jain MC, Upendra K, Majumdar D, Kumar S, Kumar U. 2000. Reducing nitrous oxide emission from an irrigated rice field of North India with nitrification inhibitors. Agric, Ecosyst Environ 81:163 – 169.

Food and Agriculture Organization (FAO). 1980. Review on Agriculture and Development-Cerescope. CERES No. 075 (Vol. 13 No. 3).

Food and Agriculture Organization (FAO)/United Nations, Education, Science and Cultural Organization (UNESCO). 1988. FAO/UNESCO soil map of the world. Revised Legend.

Fox RH, Myers RJK, Vallis I. 1990. The nitrogen mineralization rate of legume residues in soil as influenced by their polyphenol, lignin, and nitrogen contents. Plant Soil 129:251 – 259.

Freed RD. 1992. How to use MSTAT-C to analyze on-farm experiments. Farming Systems Conference. Michigan State University, East Lansing, MI.

International Institute of Tropical Agriculture (IITA). 1985. Laboratory manual of selected methods for soil and plant analysis. IITA, Ibadan, Nigeria.

Kalburtji KL, Mamolos AP, Kostopoulou S. 1997. Nutrient release from decomposing *Lotus coniculatus* residues in relation to soil pH and nitrogen levels. Agric, Ecosyst Environ 65:107 – 112.

Khan TA, Saxena SK. 1997. Integrated management of root knot nematode *Meloidogyne javanica* infecting tomato using organic materials and *Paecilomyces lilacinus*. Bioresource Technol 61:247 – 250.

Lalljee B. 1999. In: Singh RP, Saxena RC, editors. *Effect of neemcake on nitrification inhibition in an Oxisol of Mauritius. Azadirachta indica* A. Juss. Enfield, USA: Science Publishers Inc. pp 291 – 301.

Mahimairaja S, Bolan NS, Hedley MJ, Macgregor AN. 1994. Losses and transformation of nitrogen during composting of poultry manure with different amendments: An incubation experiment. Bioresource Technol 47:265 – 273.

Neem Foundation. 1997. Neem for fertilizer management. Available: www.neemfoundation.org/fert.htm. Accessed: July 2003.

Nyakatawa EZ, Reddy KC. 2000. Tillage, cover cropping and poultry litter effects on cotton: I. Germination and seedling growth. Agronomy J 95:992 – 999.

Ocio JA, Brookes PC, Jenkinson DS. 1991. Field incorporation of straw and its effects on soil microbial biomass and soil inorganic N. Soil Biol Biochem 23:171 – 176.

Riegel C, Fernandez FA, Noe JP. 1996. *Meloidogyne incognita* infested soil amended with chicken litter. J Nematol 28:369 – 378.

Reddy PP, Khan R M, Rao MS, Chari MS, Ramaprasad G. 1993. Management of root-knot nematodes infesting papaya by incorporation of some plant leaves. Botanical pesticides in integrated pest management: Proceedings of National symposium held at Central Tobacco Research Institute, Rajahmundry, India, 21 – 22 January 1990. pp 421 – 423.

Rowel DL. 1994. Soil science: methods and applications. London, UK: Longman Group Ltd.

Shah Z, Faheem A. 2000. Evaluation of indigenous plant materials for the nitrification inhibition property in soil. Sarhad J Agric 16:69 – 75.

Tisdale SL, Nelson WL, Beaton JD, Havlin JL. 1993. Soil fertility and fertilizers. 5th ed. New York: Macmillan Publishing Company.

Van Kessel JS, Reeves JB, Meisinger JJ. 2000. Nitrogen and carbon mineralization of potential manure components. J Environ Quality 29:1669 – 1677.

Wong JWC, Ma KK, Fang KM, Cheung C. 1999. Utilization of a manure compost for organic farming in Hong Kong. Bioresource Technol 67:43 – 46.