American-Eurasian J. Agric. & Environ. Sci., 3 (3): 314-324, 2008
ISSN 1818-6769

The Effects of Fertilizers on Soil Microbial Components and Chemical Properties under Leguminous Cultivation

R. Lalfakzuala, H. Kayang and M.S. Dkhar

Department of Botany, School of Life Sciences, North Eastern Hill University,
Mawlai Mawkynroh Umshing, Shillong-793 022, Meghalaya, India

Abstract: A study was conducted under the cultivation of high yielding variety of groundnut ICGS-76 (*Arachis hypogaea* L.) treated with fertilizers at an upland experimental block of Agronomy division, Indian Council of Agricultural Research (ICAR) Barapani, Meghalaya, India. The aim was to assess and compare the effect of inorganic (NPK), organic (FYM) and combination of inorganic and organic (NPK+FYM) on soil microbial components and chemical properties and groundnut yield under different stages of cropping i.e. Pre-fertilization (PF), Groundnut Cropping (GC) and Post Harvest (PHV). GC influenced soil microbial number, microbial biomass Carbon (C_{mic}) and Soil Respiration (SR) within each treatment. CTRL, FYM, NPK+FYM and FYM plots harboured higher number of microbes, C_{mic}, SR respectively. Soil enzymes activity were not influenced by groundnut cropping and maximum activity was exhibited only at FYM and NPK+FYM whereas NPK fertilization showed lower influenced on it. GC has a positive effect on soil Total Nitrogen (TN), Available Phosphorus (AP) and Moisture Content (MC). Higher amount of Total Organic Carbon (TOC) and potassium (K) were exhibited at PHV and PF. Higher MC was observed in the NPK+FYM plot and soil pH was more acidic in presence of groundnut. Application of NPK+FYM fertilization exhibited a beneficial effect on groundnut yield.

Key words: Inorganic fertilizer · organic fertilizer · microbial number · soil chemical properties · soil enzyme

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) has been accepted and considered as a vegetable oil seed crop in India during mid to late 19th century and since then occupied the first place among the oil seeds grown in the country. In the oil seed scenario of India, groundnut is the largest component, which occupies 45% of the total oil seeds area and 55% of the country's total oil seed production [1]. Recent interest in agro ecosystem research has been focused on the introduction of sustainable management practices in agriculture, including crop rotations and fertilization systems to maintain soil quality and productivity and to minimize the negative effects of agriculture production on the environment.

Land used activities particularly related to agricultural practices and forestry can have considerable impact on the size and activity of soil microbial communities and on biological health of soils [2, 3]. Nitrogen fertilizer has indeed caused a significant increase in crop yield; it has also brought about some unfavorable result. Besides the impairment of environmental quality, this practice also caused a decline in soil productivity through excessive soil erosion, nutrient runoff and deteriorated soil chemical properties [4]. The addition of certain organic fertilizers causes a net immobilization of soil nitrogen [5].

Long-term cropping systems and N fertilization can influence important soil properties such as soil structure and density, soil pH, the quantity, quality and distribution of soil organic matter and of nutrient cycles within the soil profile [6, 7]. Inorganic N fertilization can have significant effect on soil microorganisms and enzymes through higher plant yields and thus, crop residues and through its impact on soil pH depending on the amount and type of fertilizers [8]. Changes in soil microorganisms may have an important effect on the productivity of soil, since they influence the crop production by acting as catalyst for bio-transformations [9]. An understanding of microbial processes is important for the management of farming systems, particularly those that rely on organic inputs of nutrients [10].

Corresponding Author: Dr. H. Kayang, Department of Botany, School of Life Sciences, North Eastern Hill University, Mawlai Mawkynroh Umshing, Shillong-793 022, Meghalaya, India

The activity of soil microorganisms is strongly linked to the activity of enzymes and soil management (including crop rotations, fertilization and tillage and crop residue placement) strongly influences the activity of soil enzymes [11, 13]. Soil enzymes are potential indicators of soil quality because of their relationship to soil biology, ease of measurement and rapid response to changes in soil management [14]. Such an index would integrate physical, chemical and biological characteristics and be used to monitor the effects of soil management on long-term productivity [15].

Management practices significantly affected organic carbon C, carbohydrate contents, microbial biomass C and organic C turnover rates in agricultural soils [16]. The role of soil microbial biomass as a relatively labile nutrient pool in the cycling of C, N and P is well established [17]. In agro ecosystems, human intervention may affect soil biota and therefore it has a crucial impact on system productivity and its maintenance. Therefore, the depletion of organic matter level in heavily cultivated agricultural situations could considerably affect the future productivity of some soils. Since soil microorganisms can act as an indicator to show the fertility level and quality of soil, the assessment and precise study on microbial composition, their activity and quality of soil in an agro ecosystem is necessary. Various agricultural management practices such as cropping system, fertilizer application, cultivation practices, soil organic amendments and pesticide application can lead to the alteration of the microbial dynamic in the agro-ecosystem [18]. By keeping all these views the main objectives in this study were to assess the effect of organic and inorganic fertilizers on soil microbial components, chemical properties and groundnut yield under fertilization.

MATERIALS AND METHODS

Study area: Study was carried out at an upland experimental block of Agronomy division, Indian Council of Agricultural Research (ICAR) for North Eastern Hill (NEH) region complex at Barapani Shillong; Meghalaya, India on Groundnut (*Arachis hypogaea* L.) cultivation. The geographical position of the study site is at 25°38' N latitude and 91°52' E longitudes and is situated at an altitude of 850 msl. The soil of the study area has been broadly divided into four categories viz., red loamy, lateritic, red and yellow and alluvial soil. The soil of the experimental site is sandy loam (54. 50%) with moderate permeability, silt (30. 80%) and clay (14. 45%). The soil pH was slightly acidic and ranged from pH 4. 9 to pH 6. 0. The climate is humid and sub-tropical. The low clouds brought in by the south and west monsoon get interrupted in the southern face of Khasi hills and cause extremely heavy rainfall along the Cherapunjee range through long peninsular belt. The rain starts from middle of April and it continues till late October.

Experimental design: High yielding variety of groundnut ICGS-76 (International culture of groundnut selection-76) from International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Hyderabad (India) was sown for the investigation during the first year (2001) and the second year (2002). The experimental field was divided into four blocks with three replicates, each for different treatments and levels of fertilizer. The optimum fertilizers dosage for groundnut was applied into the field as recommended by ICAR (Table 1). According to the types of fertilizer treatment, each of the experimental plots viz., controls, inorganic, organic and combinations of inorganic and organic were designated as CTRL, NPK, FYM and NPK+FYM respectively (Fig. 1). The experimental block was set up in a slope land terrace, with a good drainage system. Each triplicate plot had a size of 3×4 m^2. Before sowing and adding fertilizers the field was properly ploughed. After the application of fertilizers, groundnut was sown in a 10×30 cm spacing rows as recommended by ICAR.

Table 1: Types of fertilizer treatments and doses

Treatment	Source	Dose	
1. Control (CTRL)	-	-	
2. Inorganic fertilizers (N+P+K)	N=urea	20 kg/ha	
	P=single super phosphate	60 kg/ha	Recommended dose
	K=muriate of potash	40 kg/ha	
3. Organic fertilizer (FYM)	FYM=farmyard manure (Cow dung)	10 t/ha	
4. Combination of inorganic and organic fertilizers	N	10 kg/ha	
[(N+P+K) + (FYM)]	P	30 kg/ha	50% of recommended dose
	K	20 kg/ha	
	FYM	5 t/ha	

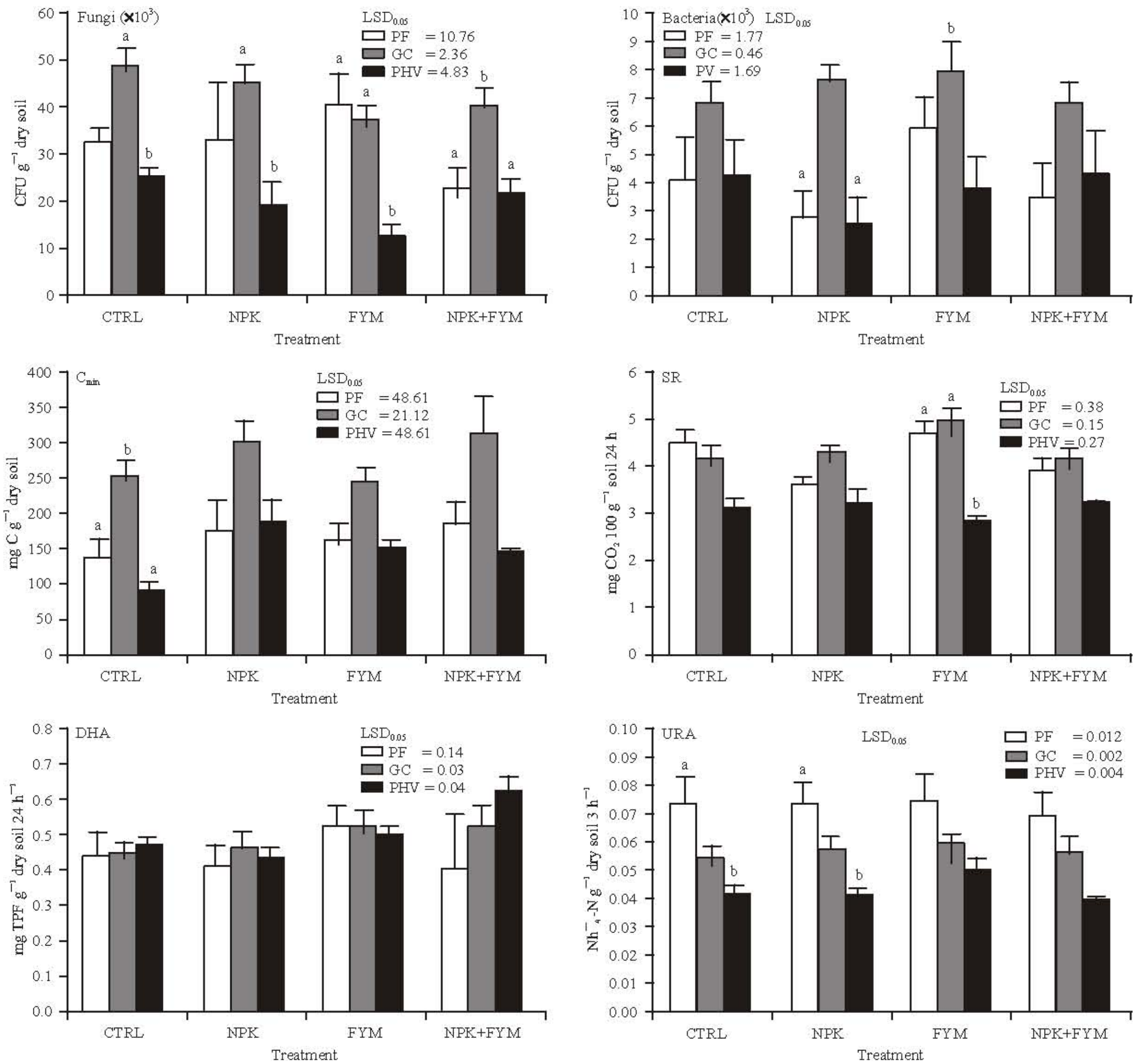

Fig. 1: Effect of groundnut growing stages (PF, GC and PHV) on soil microbial components (FP, BP, C_{mic}, SR, DHA, URA) under leguminous cultivation as influenced by organic and inorganic fertilizers. Means±SE with the same letter on the top of the bars within treatments do not differ significantly according to Scheffe multiple range test (p = 0.05)

Soil sampling and processing: Soil samples were collected randomly, aseptically from the treatments at monthly intervals during two crop cycles. Soil samples were taken from the top 100 mm at least three random positions in each plot and samples from each plot were pooled and mixed. After sieving (<2mm), approximately 300g of each sample was stored at 5°C and subsequently used for microbiological assays. The remaining ones was air dried for chemical analysis. The mean data of 2001 and 2002 were used to interpret as the effect of fertilizer on soil microbiological and chemical characteristics. The mean data in the month of April (2001 and 2002) was considered as Pre-fertilization (PF), mean data in the month of May to September (2001 and 2002) were considered as Growing Stage (GS) and the mean data in the month of October (2001 and 2002) was considered as Post Harvest (PHV).

Analyses of soil chemical properties: Soil chemical properties were determined using methods described by Allen [19]. Soil microbial biomass carbon was determined by chloroform Fumigation Incubation (FI) method [20]. Soil respiration was estimate by the method of McFadyen [12].

Isolation and counting of most platable microorganisms: The dilution plate technique [21] was employed to enumerate the most important groups of soil fungi and bacteria. Martin's rose bengal agar medium was used for the isolation of fungi [22] and nutrient agar medium [23] was used for bacteria. The Petri dishes were incubated at 25±1°C for 5 days and 30±1°C for 24 h for fungi and bacteria respectively.

Estimation of enzyme activities in soil: Dehydrogenase activity was estimated by 2-3-5-Triphenyl tetrazolium chloride (TTC) reduction technique [24] and the activity of urease was measured by the method of McGarity and Myers [25].

Statistical analysis: Variances between treatments were compared according to Duncan's multiple range test and variances between the three observed stages i.e. PF x GS x PHV were compared according to Scheffe test. Statistical analyses were performed with Microsoft Excel and Statistica 5.0 version.

RESULTS AND DISCUSSION

Soil microbial number: Number of fungi was significantly greater in the CTRL, NPK and NPK+FYM plots than FYM treatment and maximum fungal number was noted at CTRL (Table 2). GC has the maximum fungal population among the three different growing stages except FYM treatment, whereas PHV showed minimum population within all treatments. The fungal population also showed a significant variation among different growing stages within treatment (Fig. 1) Number of bacteria did not differ significantly between treatments whereas higher bacterial number was observed at FYM plot (Table 2). These results imply that generally soil microbial numbers did not differ significantly within treatments. The enrichment of soil nitrogen through biological fixation of nitrogen by the host legumes and plant composition, could have affected the microbial diversity [26]. The application of fertilizer increased the soil fertility level, the number of microorganisms and also agricultural practice particularly input of manure and cover crops have large impact on the size and activity of soil microbial communities [18, 27].

The peak of bacterial number at FYM treatment was in agreement with the earlier findings which stated that the ratios of Gram +ve to gram -ve bacteria and of bacteria to fungi, as determined signature phospholipid fatty acids, were higher in the organic treatments than in the inorganic treatments [28]. They also concluded that the organic amendments increased the C_{org} content of the soil whereas C_{org} content and C/N ratio significantly affected bacteria and eukaryotic community structures. The manure soils also supplied large amounts of readily available C, resulting in a more diverse and dynamic microbial system than in inorganically fertilized soil [2]. The lower microbial number in PF and PHV of groundnut (Fig. 1) indicated that the bacterial functional diversity in agro-ecosystems was affected by plant growing stages [29, 30]. It was noted that legumes could enrich their immediate soil environment with rhizobia through rhizosphere effect [31]. It was also observed that number of fungi and bacteria were greater during groundnut cropping rather than PF and PHV within treatments (Fig. 1). The rhizosphere is a system exposed to environmental fluctuations due to shift on composition of root exudates, which has a marked influence on microbial communities [32].

Biomass carbon and soil respiration: The C_{mic} content ranged from 211.02 mg C g^{-1} in the CTRL to 270.33 mg C g^{-1} dry soil in the NPK+FYM plot (Table 2). Though it showed insignificant variation of C_{mic} within treatment, but C_{mic} increases along with treatment where CTRL plot showed lowest amount of C_{mic} as compared with fertilized plot. Higher amount of C_{mic} was observed at GC stage within all treatments (Fig. 1). The maximum amount of C_{mic} in fertilized plots might be due to the higher accumulation

Table 2: Effect of organic and inorganic fertilizers on soil microbial components under leguminous cultivation. Means in columns followed by the same letter do not differ significantly according to Duncun's multiple range test (p=0.05). Values in parenthesis are SEMs. FP fungal population, BP bacterial population, C_{mic} microbial biomass carbon, SR soil respiration, DHA dehydrogenase activity, URA urease activity

Treatment	FP	BP	Cmic	SR	DHA	URA
CTRL	44.78a (3.04)	6.13a (0.59)	211.02a (18.13)	4.06a (0.18)	0.45a (0.02)	0.05a (0.003)
NPK	44.57a (4.5)	6.23a (0.54)	264.36a (25.95)	4.03ab (0.15)	0.45a (0.03)	0.05a (0.003)
FYM	34.34b (2.71)	7.15a (0.73)	217.38a (19.19)	4.61c (0.22)	0.51a (0.03)	0.06a (0.003)
NPK+FYM	37.52ab (2.94)	5.98a (0.64)	270.33a (38.53)	3.99ad (0.15)	0.52a (0.04)	0.05a (0.003)
$LSD_{0.05}$	1.71	0.32	13.56	0.08	0.01	0.001

of organic carbon as it was noted that soil management practice i.e. manure applications typically result in increased soluble organic C in soil or increased carbon input to the soil [33, 34]. Therefore the ratio of microbial C to soil organic carbon has thus been used as an indicator for C availability [35]. However, it was also reported that inorganic fertilizer reduced soil microbial biomass carbon [36, 37]. Thus, the control and FYM plots showed higher amount of microbial biomass carbon rather than those inorganic (NPK) treated plot [38, 39]. But it was observed that C_{mic} showed inconsistent distribution i.e. within sampling period higher C_{mic} was also noted in NPK and NPK+FYM plots. Therefore, it can be hypothesized that this inconsistent distribution could be due to the retention of fertilizers which was already applied much earlier for other experimental purposes. The analysis of variance revealed that fertilizers treatment (inorganic or organic) showed insignificant variation ($P \leq 0.05$) on microbial biomass carbon when compared to control plot.

Higher amount of C_{mic} was observed at GC stage in all the treatments (Fig. 1) with insignificant variation between PF, GC and PHV except in the CTRL plot. The higher amount of C_{mic} at GC could be due to the increased in soil microbial number (fungi and bacteria) and the effect of root exudation. The plant root exudates influences the presence and growth of soil microbial population, since the host plant was leguminous plant, it was expected to support the soil microbial population especially those of symbiotic nitrogen fixing bacteria i.e. *Rhizobium* sp. Higher number of fungi and bacteria was always recorded in GC which suggested that microbial biomass carbon measures the total biomass C (fungi + bacteria) and the specific studies have indicated that fungi are dominant component of the total soil microbial biomass accounting for up to 90% of total [40].

The effects of inorganic fertilizer application on soil microbial biomass have shown contradictory results. Some workers have reported increase in the size of microbial biomass [6, 42] whereas others have shown in the opposite [36, 41]. The reduction in C_{mic} under fertilizers treatment might be due to the high level of mineral N availability [39], changes in substrate quality and root growth [43, 39] and variation in microbial competition and community structure, repression of enzyme activity and the build-up of recalcitrant and toxic compounds [44]. The fertilizers application also suggested that it lowered the amount of soil microbial biomass carbon and the long-term soil management practices (primarily tillage and fertilizers application) led to decrease in total microbial biomass [45].

Soil respiration (SR) ranged from 3.99 mg CO_2 100 g^{-1} soil $24h^{-1}$ in the NPK+FYM plot to 4.61 mg CO_2 100 g^{-1} soil $24h^{-1}$ in the FYM plot (Table 2). SR figures in the FYM plots were significantly higher in comparison to other plots (Fig. 1). The manure soils have higher levels of soluble organic C, therefore supporting higher levels of microbial activity. The maximum soil respiration in FYM plot might be due to the enrichment of soil nutrients through the addition of high organic carbon content or the availability of active organic carbon of farmyard manure. It can be hypothesized that the maximum soil respiration in the GC rather than at the time of initial stage of fertilizers application and PHV might be due to the lower availability of organic carbon, where FYM was supposed to provide higher amount of organic carbon (Fig. 1). This hypothesis confirmed the earlier observation [46] who reported that, after 12 weeks the labile carbon substrates from the dung were likely to have become depleted, leaving large amount of dead microbial materials as a possible energy source for other microorganisms. Further, it was reported that the mean soil CO_2 evolution was greater during the growing season than during fallow in all crops [47] and legumes could enrich their immediate soil environment with rhizobia through rhizosphere effect [31]. It has also been well documented that soil CO_2 evolution was a function of root biomass [48], soil temperature and moisture [49] and fungal population [50]. The application of farmyard manure and NPK fertilizer improved population of *Azotobacter*, soil microorganisms and nodulation of soybean (legume) in the long term manuring experiment conducted in India [51]. Thus it can be assumed that the reaction of the microbial community to the addition of manure is very similar to a rhizosphere response.

Soil enzymes: Dehydrogenase activity ranged from 0.45 mg TPF g^{-1} dry soil $24h^{-1}$ in the CTRL and NPK plots to 0.52 mg TPF g^{-1} dry soil $24h^{-1}$ in the NPK+FYM plot and insignificant variation was observed within treatments (Table 2). The pre fertilization and pre-sowing of groundnut (PF) showed lower enzyme activity than GC and PHV and the result also showed insignificant variation between PF, GC and PHV within all treatments (Fig. 1). There are lots of reporting regarding the linked between soil enzyme activity and microorganisms [11, 13]. Whereas our results have shown that higher enzyme activity i.e. NPK+FYM and FYM plots do not display higher microbial numbers. The dehydrogenase activity was lower in soil that had received the largest amount of fertilizers; this suggests that dehydrogenase activity was

Table 3: Effect of organic and inorganic fertilizers on soil chemical properties under leguminous cultivation. Means in columns followed by the same letter do not differ significantly according to Duncun's multiple range test (p=0.05). Values *in parenthesis* are SEMs. MC moisture content, TOC total organic carbon, TN total nitrogen, AP available phosphorous, K potassium

Treatment	MC	pH	TOC	TN	AP	K
CTRL	23.94a (0.38)	5.48ac (0.03)	2.07a (0.02)	0.15a (0.01)	28.63a (2.11)	0.01a (0.0006)
NPK	23.68ab (0.30)	5.39a (0.03)	1.99a (0.01)	0.16a (0.01)	33.07b (2.07)	0.01bc (0.0006)
FYM	24.92cd (0.33)	5.61b 0.03)	2.23bc (0.04)	0.17a (0.009)	27.85cd (2.27)	0.01ab (0.0006)
NPK+FYM	25cd (0.43)	5.52bc (0.03)	2.31c (0.06)	0.15a (0.009)	25.75d (1.72)	0.01bc (0.0007)
$LSD_{0.05}$	0.18	0.01	0.02	0.005	0.89	0.0003

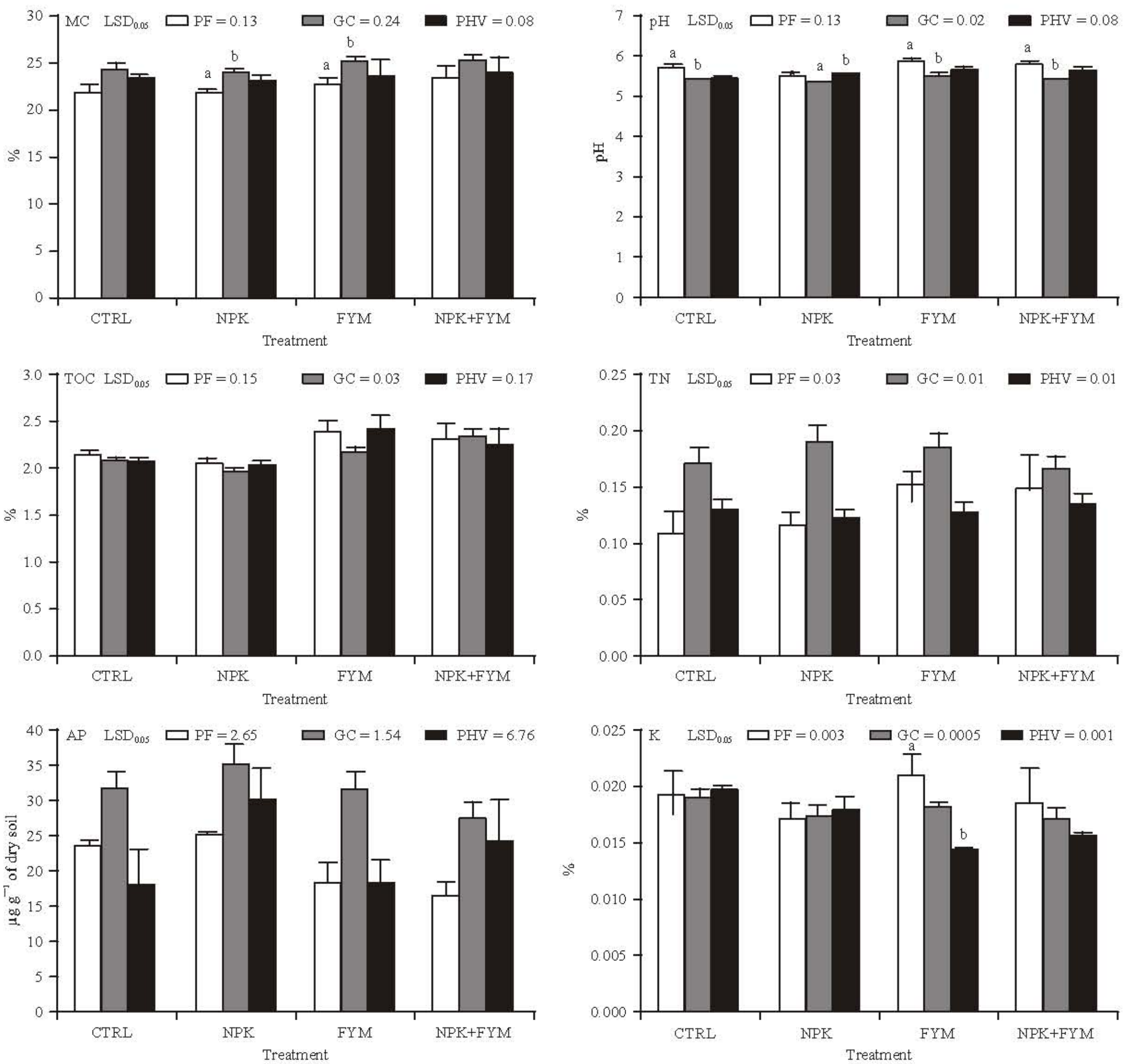

Fig. 2: Effect of groundnut growing stages (PF, GC and PHV) on soil physico-chemical properties (MC, pH, TOC, TN, AP, K) under leguminous cultivation as influenced by organic and inorganic fertilizers. Means±SE with the same letter on the top of the bars within treatments do not differ significantly according to Scheffe multiple range test (p = 0.05)

highly sensitive to the inhibitory effects associated with large amount of fertilizer additions [52]. The higher enzyme activity as observed in the manure treated plot suggested that manure promoted biological and microbial activities and accelerated the breakdown of organic substances in the added manure [53]. The highest dehydrogenase activity was observed in soil treated with manure, while lowest in the CTRL or NP-treated plots. So, the addition of FYM and NPK+FYM enhanced and promoted dehydrogenase enzyme activity. It can be hypothesized that the addition of manure saturated soil's capacity to retain manure-P and the soil P status might also influence microbial growth directly, through its effect on plant root growth and consequently influence the amount of C released by roots [54, 55]. It was also observed that dehydrogenase was significantly higher in the soil treated with cattle manure [53]. The results of insignificant variation of dehydrogenase activity within treatments indicated that there is no significant impact of individual fertilizers treatments on the dehydrogenase activity [56]. The pre fertilization and pre-sowing of groundnut (PF) showed lower enzyme activity than GC and PHV (Fig. 2). It was also reported that in the legume species, acid phosphatase and dehydrogenase activities were significantly higher in rhizospheric than in non-rhizospheric soils [57].

Urease activity ranged from 0.05 NH^{+}_{4}-N g^{-1} dry soil $3h^{-1}$ in the CTRL, NPK and NPK+FYM plots to 0.06 NH^{+}_{4}-N g^{-1} dry soil $3h^{-1}$ in the FYM plot and insignificant variation was observed within treatment (Table 2). The result also indicated that urease activity showed higher amount in the PF rather than GC and PHV within all treatments and a significant variation were observed between PF and PHV within CTRL and NPK plots (Fig. 1). The much closed result within treatment indicates that the fertilizer has a trivial influence on soil urease activity and the total, intracellular, extracellular and specific urease activities in the soils were significantly affected by crop rotation, but not by N fertilization [58]. The levels of fertilizer N as stated with earlier results also did not affect the urease activity, soil organic matter content and N_{biom} content [59]. The mean urease activity showed higher amount in the PF than GC and PHV in all treatments (Fig. 2), which indicated that the compound fertilization inhibited urease activity after six weeks of application [60]. Long-term N fertilizer application and products formed from microbial assimilation of NH_4^+ and NO_3^- in C-amended soils could suppress the urease activity [61, 62]. It has also been reported that variation in urease activity was caused by changes in organic matter content of soils [63] and legumes rotation led to greater contents of organic C and N in soils [64].

pH and moisture content: pH ranged from 5.39 in the NPK to 5.61 in the FYM plot and insignificant variation was observed (Table 3). The lowering of soil pH might be due to fertilizer application [65]. Most N-containing inorganic fertilizers, unless specially treated, tends to acidify soil. This is mainly due to the fact that most fertilizer supply NH_4^+ or result in its production. Upon oxidation NH_4^+ can release H^+ ions which are potential source of acidify [66]. It was also reported that the plots that were continuously applied with pure organic fertilizer showed slight increase in soil pH and soil organic matter content [67]. Conversely, the continuous application of pure inorganic fertilizer resulted in a decreasing trend in soil pH. Our result also showed that the soil pH in the GC stage was significantly lower than PF and PHV (Fig. 2).

Soil chemical properties (TOC, TN, AP and K): Total organic carbon (TOC) ranged from 1.99 % in the NPK plot to 2.31 % in the NPK+FYM plot and insignificant variation within treatment was observed (Table 3). GC stage showed lower TOC except in the case of NPK+FYM plot and insignificant variation of TOC between three stages in all treatment was observed (Fig. 2). The higher soil organic carbon in FYM and NPK+FYM plots might be due to the higher organic matter content in farmyard manure [68]. Soil organic matter levels and soil microbial activities, vital for the nutrient turnover and long-term productivity of the soil were enhanced by use of organic amendments along with inorganic fertilizers [69]. The peak organic carbon in NPK+FYM plot could be due to the supplies of large amounts of readily available C, resulting in a more diverse and dynamic microbial system than inorganically fertilized soil [70]. Similarly, the combination of farmyard manure with N+P and N+P+K fertilization could enable soil carbon to be maintained equal to, or greater than the native site soil [71]. In contrast, continuous inorganic fertilization was deleterious to soil quality because of depletion of organic matter, the reservoir of plant available N and P in weathered, tropical soils [72]. Insignificant variation of TOC between three stages in all treatment was observed. This result indicates that the crop has not significantly influenced on the distribution of TOC (Fig. 2).

Total nitrogen (TN) content ranged from 0.15% in the CTRL plot to 0.17 % in the FYM plot and insignificant variation was observed within treatment (Table 3). Insignificant variation between the three stages was

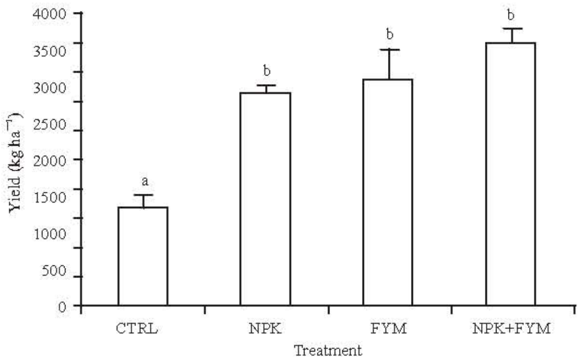

Fig. 3: Mean (2001-2002) yield of groundnut as influenced by organic and inorganic fertilizers. Means±SE with the same letter do not differ significantly according Scheffe multiple range test (p = 0.05)

observed but higher N content was noted in the GC stage and lower N content in the PHV stage within all treatments (Fig. 3).The insignificant variation within treatment could be due to the fixation of atmospheric nitrogen by groundnut through its nodules present in the root system. The higher soil N content in the treated plot was greater in all fertilized treatments as compared to the control [6, 52]. There are lots of reports on the higher soil N content in FYM treated soil [68]. However, combination of farmyard manure with N+P+K fertilization enabled N to be maintained equal to, or greater than the native site soil [71]. Further, the addition of certain organic fertilizers causes a net mobilization of soil nitrogen [5].

Available Phosphorous (AP) content showed insignificant variation within treatment and NPK plot displayed higher level of P (Table 3) which indicated that the P fertilizer application significantly increased soil P concentration [72, 73]. Further, it was also reported that little of the P fertilizer added in their experiments could be detected in the bicarbonate-extractable fraction a few days after addition [74]. Though insignificant variation of AP between cropping stages was observed, greater AP was noted in the GC stage (Fig. 2). This result suggests that groundnut has a beneficial effect on the distribution of soil AP.

The mean soil K content showed insignificant variation within treatment (Table 3) and GC stage did not displayed higher soil K as compared to PF and PHV while a significant variation was noted between PF and PHV in the FYM plot (Fig. 2). Soil K content showed insignificant variation within treatment, where NPK and NPK+FYM fertilization were expected to display higher levels of K (Table 3). GC stage did not display higher soil K as compared to PF and PHV while a significant variation was noted between PF and PHV in the FYM plot (Fig. 2). It was also reported that the soil concentrations of all the inorganic nutrients (NPK) measured were greater following fertilizer applications as compared to the unfertilized plots [52]. But our result could be due to the effects of K retention which was applied few years back for other experimental purposes. Similar results has been documented [75, 76], which they suggested that this lack of effects of removing fertilizers in the short term is due in part to the long history of fertilization and accumulation of nutrient reserves in the soil before the various experiment began.

Yield: Groundnut yield was significantly higher in the treated plot than CTRL plot (Fig. 3). These findings show that the highest yield which was noted in NPK+FYM plot could be due to the improvement of soil physical properties and nutrients, which translated to higher yield [77].

ACKNOWLEDGEMENTS

The authors are grateful to the Head, Department of Botany for providing laboratory facilities and North Eastern Council, Shillong for providing financial support in the form of project to North Eastern Biodiversity Research Cell, NEHU, Shillong and the Division of Agronomy, ICAR, Barapani, Shillong, for their cooperation and support in setting up the experimental plots.

REFERENCES

1. Munda, G.C., U.K. Hazarika, R. Singh, B.K. Sharma and J. Singh, 1997.Groundnut cultivation in North Eastern Hills. Published by the Director, ICAR Research Complex for NEH Region, Meghalaya, India, pp: 1.
2. Kirchner, M.J., A.F. Wollum II and L.D. King, 1993. Soil microbial populations and activities in reduced chemical input agro-ecosystem. Soil Sci. Soc. Amsterdam J., 57: 1289-1295.
3. Resenzweig, C. and M.L. Parry, 1994. Potential impact of climate change on world food supply. Nature, 367: 133-556.
4. Kang, B.T., 1993. Changes in soil chemical properties and crop performance with continuous cropping on an Entisol in the humid tropics. In: Mulongoy, K. and R. Merckx (Eds.). Soil organic matter dynamic and sustainability of tropical agriculture, John Wiley and Sons, New York, pp: 297-305.

5. Murwira, H. and H. Kirchmann, 1993. Carbon and nitrogen mineralization of cattle manures, subject to different treatments, in Zimbabwean and Swedish soils. In: Mulongoy, K. and R. Merckx (Eds.). Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture, John Wiley and Sons, New York, pp: 189-198.
6. Omay, A.B., C.W. Rice, L.D. Maddux and W.B. Gordon, 1997. Changes in soil microbial and chemical properties under long-term crop rotation and fertilization. Soil Sci. Soc. Amsterdam J., 61: 1672-1678.
7. Senwo, Z.N. and M.A. Tabatabai, 1998. Amino acid composition of soil organic matter. Biol. Fert. Soils, 26: 235-242.
8. Tabatabai, M.A., M.H. Fu and N.T. Basta, 1992. Effects of cropping systems on nitrification in soils. Community of Soil Science and Plant Analysis, 23: 1885-1891.
9. Roder, W., S.C. Mason, M.D. Cleff, J.W. Doran and K.R. Knieo, 1988. Plant and microbial responses to Sorghum-soybean cropping systems and fertility management. Soil Sci. Soc. Amsterdam J., 52: 1337-1342.
10. Smith, J.L. and E.A. Paul, 1990. The significance of soil microbial biomass estimation. In: Bollag, T.M. and G. Stotzky (Eds.). Soil Biochemistry, Marcel Dekker, New York.
11. Deng, S.P. and M.A Tabatabai, 1997. Effect of tillage and residue management on enzyme activities in soils. III Phosphatases and arylsulphatase. Biol. Fert. Soils, 22: 208-213.
12. Mcfadyen, A., 1970. Soil metabolism in relation to ecosystem energy flow and to primary and secondary production. In: J Unesco. IBP (Eds.), Method of Study in Soil Ecology. Proc. Paris Symp., Paris, pp: 167-172.
13. Klose, S., J.M. Moore and M.A. Tabatabai, 1999. Arylsulphatase activity of microbial biomass in soils as affected by cropping systems. Biol. Fert. Soils, 29: 46-54.
14. Dick, R.P. and D. Breakwill and R. Turco, 1996. Soil enzyme activities and biodiversity measurements as integrating biological indicators. In Doran, J.W. and A.J. Jones (Eds.). Handbook of Methods for Assessment of Soil Quality. Soil Sci. Soc. Am., Madison, pp: 247-272.
15. Doran, J.W. and T.B. Parkin, 1994. Defining and Assessing Soil Quality. In: Doran, J.W., D.C. Coleman, D.F. Bezdicek, B.A. Stewart (Eds.). Defining soil quality for a sustainable environment. Soil Sci. Soc. Am., Madison, pp: 3-21.
16. Hu, S., D.C. Coleman, C.R. Carroll, P.F. Hendrix and M.H. Beare, 1997. Labile soil carbon pools in subtropical forest and agricultural ecosystems as influenced by management practices and vegetation types. Agric. Ecos. Environ., 65: 69-78.
17. Jenkinson, D.S. and L.C. Parry, 1989. Nitrogen cycle in the broad balk wheat experiment: A model for the turnover of nitrogen through the soil microbial biomass. Soil Biol. Biochem., 21: 535-541.
18. Tilak, K.V.B.R., A.R. Saxena and Datt Naveen, 1995. Dynamic of microbes in Agricultural soil with different management practices. J. Soil Biol. Ecol., 15: 117-126.
19. Allen, S.E., H.M. Grinshaw, J.A. Parkinson and C. Quarmby, 1974. Chemical Analysis of Ecological materials. Blackwell Scientific Publications, Oxford.
20. Anderson, J.M. and J.S. I. Ingram, 1993. Tropical Soil Biology and Fertility: A handbook of methods. CAB International, Oxford.
21. Parkinson, P., T.R.G. Gray and S.T. William, 1971. Methods for studying the ecology of soil microorganisms, Blackwell Scientific Publication Oxford, pp: 116.
22. Johnson, L.F. and E.A. Curl, 1972.Methods for research on ecology of soil plant pathogens. Minneapolis, Burgess Publishing Co.
23. Difco Manual, Difco laboratories, Defroit, Mich, 1953.
24. Casida, L.E., 1977. Microbial metabolic activity in soil as measured by dehydrogenase determination. Applied Environ. Microbiol., 34: 630-636.
25. McGarity, J.W. and M.C. Myer, 1967. A survey of Urease activities in soil of northern new south Wales. Plant and Soil, 27: 217-238.
26. Bardgett, R.D. and A. Shine, 1999. Linkages between litter diversity, soil microbial biomass and ecosystem function in temperate grasslands. Soil Biol. Biochem., 31: 317-321.
27. Kanazawa, S., S. Asakawa and Y. Takai, 1998. Effect of fertilizer and manure application on microbial numbers, biomass and enzyme activities in volcanic ash soils. I. Microbial numbers and biomass carbon. Soil Science and Plant Nutrition, 34: 429-439.
28. Kandeler, P.M.E. and B. Marschner, 2003. Structure and function of the soil microbial community in a long-term fertilizer experiment. Soil Biol. Biochem., 35: 453-461.
29. Lahav (Lavian), I. and Y. Steinberger, 2001. Soil bacterial functional diversity in a potato field. Euro. J. Soil Biol., 37: 59-67.

30. Zak, J.C., M.R. Willig, D.L. Moorhead and H.G. Wildman, 1994. Functional diversity of microbial communities: A quantitative approach. Soil Biol. Biochem., 26: 1101-1108.
31. Thies, J.E., P.L. Woomer and P.W. Singleton, 1995. Enrichment of bradyrhizobium spp populations in soil due to cropping of the homologous host legume. Soil Biol. Biochem., 27: 633-636.
32. Lynch, J.M. and J.M. Whipps, 1990. Substrate flow in the rhizosphere, Plant and Soil, 129: 1-10.
33. Gregorich, E.G., P. Rochette, S. McGuire, B.C. Liang and R. Lessard, 1998. Soluble organic and carbon dioxide fluxes in maize fields receiving spring-applied manure. J. Environ. Quality, 27: 209-214.
34. Liang, B.C., A.F. Mackenzie, M. Schnitzer, C.M. Monreal, P.R. Voroney and R.P. Beyaert, 1998. Management-induced change in labile soil organic matter under continuous corn in eastern Canadian soils. Biol. Fert. Soils, 26: 88-94.
35. Insam, H. and K.H. Domsch, 1988. Relationship between soil organic carbon and microbial biomass carbon on chronosequences of reclamation sites. Microbial. Ecol., 15: 177-188.
36. Ladd, J.N., M. Amato, Z. Li-Kai and J.E. Schultz, 1994. Differential effects of rotation, plant residue and nitrogen fertilizer on microbial biomass and organic matter in an Australian alfisol. Soil Biol. Biochem., 26: 821-831.
37. McAndrew, D.W. and S.S. Malhi, 1992. Long-term N fertilization of a solonetzic soil: effects on chemical and biological properties. Soil Biol. Biochem., 27: 1245-1250.
38. Hopkins, D.W. and R.S. Shield, 1996. Size and activity and soil microbial communities in long-term experimental grassland plots treated with manure and inorganic fertilizers. Biol. Fert. Soils, 22: 66-70.
39. Lovell, R.D., S.C. Jarvis and R.D. Bardgett, 1995. Soil microbial biomass and activity in long-term grassland: effects of management changes. Soil Biol. Biochem., 27: 969-975.
40. Polyanskaya, L.M., S.M. Lukin and D.G. Zvyaginzev, 1997. Changes of soil microbial biomass composition at soil cultivation. Soil Sci., 2: 206-212.
41. Henrot, J. and G.P. Robertson, 1994. Vegetation removal in two soils of humid tropics: Effects on microbial biomass. Soil Biol. Biochem., 26: 111-116.
42. Fraser, D.G., J.W. Doran, W.W. Sahs and G.W. Lesoing, 1988. Soil microbial populations and activities under conventional and organic management. J. Environ. Quality, 17: 585-590.
43. Hassink, J., 1992 Effects of soil texture and structure on carbon and nitrogen mineralisation in grassland soils. Biol. Fert. Soils, 14: 126-134.
44. Fog, K., 1988. The effect of added nitrogen on the rate of decomposition of organic matter. Biol. Rev., 63: 433-462.
45. Ananyeva, N.D., T.S. Demkina, W.J. Jones, M.L. Caberra and W.C. Steen, 1999. Microbial biomass in soils of Russia under long-term management practices. Biol. Fert. Soils, 29: 291-299.
46. Lovell, R.D. and S.C. Jarvis, 1996. Effect of cattle dung on soil microbial biomass C and N in a permanent pasture soil. Soil Biol. Biochem., 28: 291-299.
47. Franzluebbers, A.J., F.M. Hons and D.A. Zuberer, 1995. Tillage and crop effects on seasonal dynamics of soil CO_2 evolution, water content, temperature and bulk density. Applied Soil Ecol., 2: 95-109.
48. Behera, N., S.K. Joshi and D. Pati, 1990. Root contribution to total soil metabolism in a tropical soil from Orissa, India. For. Ecol. Manag., 36: 125-134.
49. Peterjohn, W.T., J.M. Melillo, P.A Stuedler, K.M. Newkirk, F.P. Bowles and J.D. Aber, 1994. Responses of trace gas fluxes and N availability to experimentally elevated soil temperatures, Ecol. Appl., 4: 617-625.
50. Vose, J.M., K.J. Elliot, D.W. Johnson, R.F. Walker, M.G. Johnson and D.T. Tingey, 1995. Effects of elevated CO_2 and N fertilization on soil respiration from ponderosa pine (*Pinusponderosa* Doug. Ex Laws.). Can. J. For. Res., 25: 1243-1251.
51. Nambiar. K.K.M., 1994. Soil Fertility and Crop Productivity under Long-Term Fertilizer use in India. Ind. Council of Agric. Res., New Delhi, India.
52. Simek, M., D.W. Hopkins, J. Kalcík, T. Picek, H. Santrucková, J. Stana and K. Trávník, 1999. Biological and chemical properties of arable soils affected by long-term organic and inorganic fertilizer applications. Biol. Fert. Soils, 29: 300-308.
53. Parham, J.A., S.P. Deng W.R. Raun and G.V. Johnson, 2002. Long-term cattle manure application in soil I. Effect of soil phosphorus levels, microbial biomass C and dehydrogenase and phosphatase activities. Biol. Fert. Soils, 35: 328-337.
54. James, D.W., J. Kotuby-Amacher, G.L. Anderson and D.A. Huber, 1996. Phosphorus mobility in calcareous soil under heavy manuring. J. Environ. Quality, 25: 770-775.
55. Perrott, K.W. and S.V. Sarathchandra, 1989. Phosphorus in the biomass of New Zealand soils under established pasture. New Zealand J. Agric. Res., 32: 409-413.
56. Tiwari, S.C., 1996. Relationship between enzyme activities and microbial population and soil respiration in some Indian soils. J. Soil Biol. Ecol., 16: 17-26.

57. Izaguirre-Mayoral, M.L., S. Flores and O. Carballo, 2002. Determination of acid phosphatase and dehydrogenase activities in the rhizosphere of nodulated legume species native to two contrasting savanna sites in Venezuela. Biol. Fert. Soils, 35: 470-472.
58. Klose, S. and M.A. Tabatabai, 2000. Urease activity of microbial biomass in soils as affected by cropping systems. Biol. Fert. Soils, 31: 191-199.
59. Roscoe, R., C.A. Vasconcellos, A.E. Furtini-Neto, A.A.G. Guedes and L.A. Fernandes, 2000. Urease activity and its relation to soil organic matter, microbial biomass nitrogen and urea-nitrogen assimilation by maize in a Brazilian Oxisol under no-tillage and tillage systems. Biol. Fert. Soils, 32: 52-59.
60. Schiner, F.A., R. Neederbacher and T. Neuwinger, 1980. Influence of compound fertilizer and cupric sulfate on soil enzymes and CO_2 evolution. Plant and Soil, 57: 85-93.
61. Dick, R.P., P.E. Rasmusen and E.A. Kesle, 1998. Influence of long-term residue management on soil enzyme activities in relation to soil chemical properties of a wheat fallow system. Biol. Fert. Soils, 6: 1259-1264.
62. McCarty, G.W., D.R. Shogren and J.M. Bremner, 1992. Regulation of urease production in soil by microbial assimilation of nitrogen. Biol. Fert. Soils, 12: 261-264.
63. Bremner, J.M and C.S. Mulvaney, 1978. Urease activity in soils. In: Burns, R.G. (Eds.). Soil enzymes, Academic Press, London, pp: 149-197.
64. Bolton, J., L. F Elliot, R.P. Papendick and D.F. Bezdicek, 1985. Soil microbial biomass and selected soil enzyme activities: Effect of fertilization and cropping practices. Soil Biol. Biochem., 17: 297-302.
65. Aref, S. and M.M. Wander, 1998. Long-term trends of corn yield and soil organic matter in different crop sequences and soil fertility treatments on the Morrow Plots. Adv. Agron., 62: 153-161.
66. Magdoff, F., L. Lanyon and B. Liebhardt, 1997. Nutrient cycling, transformations and flows: Implications for a more sustainable agriculture. Adv. Agron., 60: 1-73.
67. Colting, R.D., 1997. Revitalizing degraded soils for organic farming of vegetables. Philippine J. Crop Sci., Philippines, 22 (supplement no.1): 31.
68. Saviozzi, A., A. Biasci, R. Riffaldi and R. Levi-Minzi, 1999. Long-term effects of farmyard manure and sewage sludge on some soil biochemical characteristics. Biol. Fert. Soil, 30: 100-106.
69. Goyal, S., K. Chander, M.C. Mundra and K.K. Kapoor, 1999. Influence of inorganic fertilizers and organic amendments on soil organic matter and soil microbial properties under tropical conditions. Biol. Fert. Soils, 29: 196-200.
70. Peacock, A.D., M.D. Mullen, D.B. Ringelberg, D.D. Tyler, D.B. Hedrick, P.M. Gale and D.C. White, 2001 Soil microbial community responses to dairy manure or ammonium nitrate applications. Soil Biol. Biochem., 33: 1011-1019.
71. Agbenin, J.O. and J.T. Goladi, 1997. Carbon, nitrogen and phosphorus dynamics under continuous cultivation as influenced by farmyard manure and inorganic fertilizers in the savanna of northern Nigeria. Agric. Ecos. Environ., 63: 17-24.
72. Agbenin, J.O. and J.T. Goladi, 1998. Dynamics of phosphorus fractions in a savanna Alfisol under continuous cultivation. Soil Use Manage, 14: 59-64.
73. Ishaq, M., M. Ibrahim and R. Lal, 2002. Tillage effects on soil properties at different levels of fertilizer application in Punjab. Pak. Soil Tillage Res., 68: 93-99.
74. Scholefield, D. and A.C. Stone, 1995. Nutrient losses in runoff water following application of different fertilizers to grassland cut for silage. Agric. Ecos. Environ., 55: 181-191.
75. Bardgett, R.D. and D.K. Leeman, 1994. The short-term effects of cessation of fertilizer applications, liming and grazing on microbial biomass and activity in a reseeded upland grassland soil. Biol. Fert. Soils, 19: 148-154.
76. Sarathchandra, S.U., K.W. Perrot, M.R. Boase and J.E. Waller, 1988. Seasonal changes and the effects of fertilizer on some chemical, biochemical and microbiological characteristics of high producing pastoral soil. Biol. Fert. Soils, 6: 328-335.
77. Anikwe, M.A.N., M.E. Obi and M.M. Agbim, 2003. Effect of crop and soil management practices on soil compatibility in maize and groundnut plots in a Paleustult in Southeastern Nigeria. Plant and Soil, 25: 457-465.