International Journal of Plant & Soil Science
10(5): 1-8, 2016; Article no.IJPSS.25828
ISSN: 2320-7035

SCIENCEDOMAIN *international*
www.sciencedomain.org

Nutrient Release Patterns of Tithonia Compost and Poultry Manure in Three Dominant Soils in the Southern Guinea Savanna, Nigeria

G. O. Kolawole[1*]

[1]Department of Crop Production and Soil Science, Ladoke Akintola University of Technology, PMB 4000, Ogbomoso, 210001, Oyo State, Nigeria.

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/25828
Editor(s):
(1) Yong In Kuk, Department of Development in Oriental Medicine Resources, Sunchon National University, South Korea.
Reviewers:
(1) Olowoake Adebayo Abayomi, Kwara State University, Nigeria.
(2) Omoregbee Osazuwa, University of Benin, Nigeria.
Complete Peer review History: http://sciencedomain.org/review-history/14286

Original Research Article

Received 22nd March 2016
Accepted 14th April 2016
Published 21st April 2016

ABSTRACT

Aim: Incubation experiment was conducted to determine nutrient release patterns of tithonia compost and poultry manure in three dominant soils in the southern Guinea savanna, Nigeria.
Study Design: Complete randomized design replicated three times.
Methodology: Two- kilogram surface soil (0-15 cm depth) each of the three dominant soils, (Itagunmodi (Rhodic Paleutult), Egbeda (Oxic Paleustult), and Majeroku (Abruptic Tropaqualf) was weighed into plastic pots, replicated three times and arranged in a completely randomized design. *Tithonia diversifolia* compost (tithonia) and poultry manure were applied at the rate of 5 tDM ha^{-1} to each pot as necessary. Pots without compost were included for comparison. The pots were covered with a double layer of 0.05 mm thick polyethylene film. At the end of 0, 7, 21, 28, 35 and 42 days, the incubated soil was sampled and analyzed for pH, N and P contents.
Results: Compared with the control, incubation of organic residues increased soil pH, however, changes in soil pH varied in the soils. Poultry manure was more effective in reducing soil acidity in Majeroku (Abruptic Tropaqualf) and Itagunmodi (Rhodic Paleutult) soils than in Egbeda (Oxic Paleustult) soil. Mean changes in available P with incubation of tithonia compost were 1.2, 1.65 and 3.07 mg kg^{-1} in Egbeda, Itagunmodi and Majeroku soils respectively while with the incubation of poultry manure were 3.79, 1.92 and 6.06 mg kg^{-1} in the three soils respectively. Incubation of the

____

**Corresponding author: E-mail: oladejokolawole@hotmail.com, ogkolawole@lautech.edu.ng;*

residues reduced available N except for poultry manure which enhanced N availability in Majeroku soil.

Conclusion: Nutrient release pattern of the residues varied with soil types and are dependent on soil characteristics that may influence nutrient use efficiency by crops. Poultry manure was more effective in increasing P availability in the soils than tithonia compost.

Keywords: Incubation time; Nigeria; nutrient release; poultry manure; soil types; tithonia compost.

1. INTRODUCTION

Tropical soils generally have low organic carbon contents [1], and inclusion of organic matter is of primary importance in maintaining soil fertility, productivity and sustainability, especially in organic farming systems [2].

Soil degradation, a current concern world-wide, results from improper land-use and cultivation leading to nutrient deficiency and low plant productivity. Currently, agriculture often results in exploitation of soil productivity without adequate attention being paid to restoring the fertility of the degraded soil. Soil degradation is one of the major constraints in meeting the increasing world demand for food. This can be addressed if the benefits of organic matter are optimized. For long-term sustainable agricultural development, conservation of natural resources, especially soil organic matter (SOM), the product of decomposition of organic compound added to the soil, and a good indicator of soil quality, is considered a key measure for ameliorating degraded soils [3]. Hence addition of plant residues has now become a pivotal strategy for soil fertility improvement and sustainable land use [3]. Knowledge of the processes involved in the plant residue decomposition is critical to integrated and sustainable agricultural management [4]. Nutrient release during decomposition is particularly interesting in terms of nutrient availability to soil microorganisms as well as plants [5-7]. Decomposition processes are affected by factors such as nutrient availability, soil microorganisms, crop residue quality and physical environment [8].

Soil characteristics may influence nutrient release patterns of organic residues added to the soil. Knowledge of nutrient availability from added organic residues in different soil types will be valuable for efficient nutrient management and in maintaining synchrony between nutrient release and plant uptake. In the past, several researchers have studied the beneficial effects of Tithonia and poultry manure as sources of nutrients in soils [9,10]. The roles of nitrogen and phosphorus in plant nutrition cannot be overemphasized as they participate in a wide range of physiological and biochemical processes which culminate in improve performance and yield of plants. Phosphorus is needed by plant in relatively large quantities along side with nitrogen. The use of organic ameliorants had been reported to enrich the soil with organic matter which improve soil physical properties such a water infiltration, aeration and tilth, react with clay minerals and reduce P sorption characteristics of the soil thereby making more P available for plant use [11].

The purpose of this experiment therefore was to determine whether nutrient release patterns of Tithonia compost and poultry manure will differ in three dominant soil series in the southern Guinea savanna of Nigeria.

2. MATERIALS AND METHODS

The experiment was conducted in the laboratory of the Department of Crop Production and Soil Science, Ladoke Akintola University of Technology (LAUTECH) in Ogbomoso (Longitude 4° 10’ E, Latitude 8° 10’ N and altitude 213 m asl), Oyo state, Nigeria, during June-July 2010. Surface soil (0-15 cm depth) of three dominant soil series in the southern Guinea savanna of Nigeria, (Itagunmodi (Rhodic Paleutult), Egbeda (Oxic Paleustult), and Majeroku (Abruptic Tropaqualf) were collected from three study sites in Oyo and Osun states, Nigeria. The soils were air-dried, sieved through a 2 mm sieve and sub samples were taken for laboratory analysis. Two- kilogram of each soil type was weighed into fifteen plastic pots for each of the organic residues and replicated three times and arranged in a completely randomized design. Tithonia compost and poultry manure were applied at the rate of 5 tDM ha^{-1} to each pot as necessary. Pots without compost were included for comparison.

At the onset of the experiment, each pot received 1.2 L of distilled water to adjust the soil moisture content to 50% water holding capacity. The pots were covered with a double layer of 0.05 mm thick polyethylene film (to allow gas but not water exchange). At the end of each incubation period (0, 7, 21, 28, 35 and 42 days), the incubated soil was sampled with the aid of an iron pipe (diameter 24 mm) and analyzed for soil pH, N and P contents. Data collected were subjected to analysis of variance and where F-test showed significance, means were separated at 5% probability level with Least Significant Difference (LSD). Correlations among soil parameters were also conducted with the aid of SAS software package [12].

3. RESULTS

3.1 Chemical Composition of Organic Residues and Initial Properties of the Soils

Poultry manure had higher nitrogen (N), phosphorus (P), and potassium (K) contents than Tithonia compost (Table 1). The three soils differ in both physical and chemical properties. Majeroku soil had more sand fraction; Itagunmodi soil contained more clay fraction, while Egbeda soil had more silt fraction. Itagunmodi soil was more acidic, had the least available P, but highest total N and organic carbon contents. Egbeda soil was the least acidic, contained highest available P. Majeroku soil had the least available P, total N and organic carbon contents (Table 2).

Table 1. Nitrogen, P and K contents of the organic materials used for the experiment

Organic residues	N (%)	P (%)	K (%)
Tithonia compost	2.26	0.95	2.13
Poultry manure	2.98	1.31	2.34

3.2 Soil pH

Compared with the control, incubation of organic residues increased soil pH. Changes in soil pH with increasing time of incubation of tithonia compost varied in the three soil series. Soil pH decreased with time of incubation in Egbeda and Itagunmodi soil series. However, pH increased with increase in incubation time in Majeroku soil. Incubation of tithonia compost was more effective in reducing soil acidity in both Majeroku and Itagunmodi soils than in Egbeda soil (Table 3). Compared with the control, reduction of soil acidity, as influenced by incubation of tithonia compost in Egbeda soil, ranged between 0.38 and 0.65 units except at 28 days after incubation (DAI) with 1.03 unit changes. In Itagunmodi soil, reduction of soil acidity ranged between 0.53 and 0.77 units, while in Majeroku soil, the range was between 0.75 and 1.20 units.

Incubation of poultry manure had little or no effect in reducing soil acidity compared with the control as incubation time increased (except at 28 DAI) in Egbeda soil, it increased soil pH in Majeroku soil (range of -0.15 and 0.80 units from 14 – 42 DAI) and in Itagunmodi soil, compared with the control, changes in soil pH was from 0.15 units at 14 DAI and1.30 units at 42 DAI (Table 4). Therefore, incubation of poultry manure was more effective in reducing soil acidity in Majeroku and Itagunmodi soils than in Egbeda soil.

3.3 Soil P

Incubation of both tithonia compost and poultry manure compared with the control enhanced P availability in all the soils. However, the degree of improvement in P availability varied among the soils. With incubation of tithonia compost, there was increase in available P in Egbeda soil from the 14^{th} to the 35^{th} DAI and a decline in P at 42 DAI. In Itagunmodi soil, the increase was linear from the 14th to the 42th DAI. However, in Majeroku soil, there was a sharp increase in P at 14 DAI and gradual decrease thereafter till 42 DAI (Table 3). Changes in soil P availability over time with incubation of poultry manure were more pronounced in Majeroku soil and least in Itagunmodi soil (Table 4).

3.4 Soil N

Compared with the control, incubation of tithonia compost, generally caused reduction in soil N with increase in incubation time for all the soils (Table 3) except at the 14^{th} and 42^{nd} DAI when there were slight increases in soil N in Majeroku soil. Incubation of poultry manure similarly caused reduction in soil N in Egbeda and Itagunmodi soils except at 35 DAI for Egbeda soil and 28 DAI for Itagunmodi soil when there were slight increases. Contrarily, incubation of poultry manure resulted in increase in soil N throughout the incubation period in Majeroku soil (Table 4).

Table 2. Physical and chemical properties of three dominant soil series in southwestern Nigeria

Properties	Itagunmodi	Egbeda	Majeroku
Sand (g kg^{-1})	590	690	810
Silt (g kg^{-1})	150	190	90
Clay (g kg^{-1})	260	120	100
Textural class	**Sandy clay loam**	**Sandy loam**	**Loamy sand**
Soil pH-H_2O	4.5	5.3	4.9
Ex.Ca (cmol kg^{-1})	2.05	2.12	0.96
Ex. Mg (cmol kg^{-1})	0.66	0.49	0.36
Ex. K (cmol kg^{-1})	0.14	0.12	0.16
Ex. Na (cmol kg^{-1})	0.31	0.31	0.37
Ex. Fe (ppm)	149.78	156.46	138.67
Available P (mg kg^{-1})	1.21	7.34	3.27
Total N (g kg^{-1})	1.11	0.52	0.37
Organic C (g kg^{-1})	10.84	5.39	3.41

Table 3. Changes in pH, available P and nitrogen in three dominant soil series in southwestern Nigeria during incubation with tithonia compost

	Soil series								
	Egbeda			Itagunmodi			Majeroku		
	Control	Tithonia	Δ	Control	Tithonia	Δ	Control	Tithonia	Δ
Days after incubation	**Soil pH (H_2O)**								
14	4.35	5.00	0.65	5.05	5.70	0.65	5.10	6.03	0.93
21	4.55	4.93	0.38	4.75	5.40	0.65	4.95	5.70	0.75
28	4.20	5.23	1.03	4.70	5.47	0.77	4.80	5.67	0.87
35	4.30	4.93	0.63	4.75	5.43	0.68	4.70	5.60	0.90
42	4.40	4.83	0.43	4.70	5.23	0.53	4.80	6.00	1.20
Mean	4.36	4.98	0.62	4.79	5.45	0.66	4.87	5.80	0.93
	Phosphorus (mg/kg)								
	Control	**Tithonia**	**Δ**	**Control**	**Tithonia**	**Δ**	**Control**	**Tithonia**	**Δ**
14	2.54	3.30	0.76	1.12	2.24	1.12	2.61	7.11	4.50
21	2.74	4.15	1.41	1.19	2.45	1.26	2.63	6.64	4.01
28	2.39	3.94	1.55	1.07	2.42	1.35	2.74	4.97	2.23
35	2.62	4.19	1.57	1.03	3.16	2.13	2.87	4.61	1.74
42	2.70	3.41	0.71	1.06	3.47	2.41	2.99	5.85	2.86
Mean	2.60	3.80	1.2	1.09	2.75	1.65	2.77	5.84	3.07
	Nitrogen (%)								
	Control	**Tithonia**	**Δ**	**Control**	**Tithonia**	**Δ**	**Control**	**Tithonia**	**Δ**
14	0.173	0.143	- 0.030	0.106	0.105	- 0.001	0.039	0.050	0.011
21	0.172	0.147	- 0.025	0.139	0.116	- 0.023	0.049	0.043	- 0.006
28	0.173	0.125	- 0.048	0.108	0.103	- 0.005	0.047	0.047	0.000
35	0.168	0.155	- 0.013	0.106	0.102	- 0.004	0.053	0.047	- 0.006
42	0.178	0.161	- 0.017	0.138	0.118	- 0.020	0.050	0.052	0.002
Mean	0.173	0.146	-0.027	0.119	0.109	-0.011	0.048	0.048	

3.5 Correlation among Soil Nutrients

With incubation of tithonia compost, for Egbeda soil, pH was significantly negatively correlated with soil N (r = − 0.91), positively correlated with soil P (r = 0.79). Soil N was negatively correlated with soil P (r = − 0.81). For Itagunmodi soil, pH was negatively correlated with N (r= − 0.46) and P (r= − 0.64). For Majeroku soil, pH was positively correlated with P (r = 0.68). Correlation among other parameters were not significant. Also with incubation of poultry manure, for Egbeda soil, soil pH was significantly negatively correlated with soil N (r = − 0.93), but positively correlated with P (r = 0.57). Soil N was negatively correlated with soil P (r = − 0.50).Soil pH, N and P were not correlated in Itagunmodi soil but pH was positively and significantly correlated with P (r = 0.65) in Majeroku soil series.

Table 4. Changes in pH, available P and nitrogen in three dominant soil types in southwestern Nigeria during incubation of poultry manure

	Soil series								
	Egbeda			Itagunmodi			Majeroku		
Days after incubation	Control	Poultry manure	Δ	Control	Poultry manure	Δ	Control	Poultry manure	Δ
				Soil pH (H_2O)					
14	4.35	4.35	0.00	5.05	4.90	- 0.15	5.10	5.25	0.15
21	4.55	4.45	- 0.10	4.75	5.00	0.25	4.95	5.50	0.60
28	4.20	4.85	0.65	4.70	5.15	0.45	4.80	5.20	0.40
35	4.30	4.40	0.10	4.75	5.10	0.35	4.70	5.10	0.40
42	4.40	4.55	0.15	4.70	5.50	0.80	4.80	6.10	1.30
Mean	4.36	4.52		4.79	5.13		4.87	5.43	0.57
				Phosphorus (mg/kg)					
	Control	Poultry manure	Δ	Control	Poultry manure	Δ	Control	Poultry manure	Δ
14	2.54	7.07	4.53	1.12	3.60	2.48	2.61	9.10	6.50
21	2.74	6.74	4.00	1.19	3.03	1.84	2.63	8.68	6.05
28	2.39	6.71	4.32	1.07	2.59	1.52	2.74	9.87	7.13
35	2.62	5.06	2.44	1.03	2.74	1.71	2.87	8.52	5.65
42	2.70	6.38	3.68	1.06	3.13	2.07	2.99	7.96	4.97
Mean	2.60	6.39	3.79	1.09	3.02	1.92	2.77	8.83	6.06
				Nitrogen (%)					
	Control	Poultry manure	Δ	Control	Poultry manure	Δ	Control	Poultry manure	Δ
14	0.173	0.161	- 0.012	0.106	0.106	0.000	0.039	0.050	0.011
21	0.172	0.172	0.000	0.139	0.106	- 0.033	0.049	0.052	0.003
28	0.173	0.120	- 0.053	0.108	0.116	0.008	0.047	0.060	0.013
35	0.168	0.173	0.005	0.106	0.104	- 0.002	0.053	0.115	0.062
42	0.178	0.170	- 0.008	0.138	0.132	- 0.006	0.050	0.051	0.001
Mean	0.173	0.159		0.119	0.113		0.048	0.066	0.018

4. DISCUSSION

The observation that the organic residues generally increased soil pH compared with the control is in tandem with the reports of previous workers [13,14]. The soil pH changes observed may be due to nitrogen transformations and release of metal cations as the organic residues decompose [13]. Under anaerobic conditions, $NH4^+$ produced by the ammonification process would accumulate due to inhibition of nitrification, and the pH would increase. There are several different mechanisms that have been suggested to explain the initial rise in soil pH when organic amendments are applied to soils. These include oxidation of organic- acid anions present in the decomposing residues, ammonification of residue organic N, specific adsorption of organic molecules produced during residue decomposition and reduction reactions induced by anaerobiosis [15].

Similarly, application of organic residues increased soil available P compared with the control. This is an indication of the high percentage of soluble P in both tithonia compost and poultry manure. Fast net P mineralization may occur because both organic residues used in this study had a higher P concentration than the critical level of 0.25% required for net P mineralization [16]. The increase in soil P with incubation of the organic residues is in line with works of Laboski and Lamb, [17]; Spychaj-Fabisiak et al. [18]. The authors noted that the increase in P availability with time is likely due to microbial facilitated mineralization of soil organic P, to form inorganic P at a faster rate than that of P sorption by the soils of low to moderate P sorption capacity. Majeroku and Egbeda soils used in this study have low to moderate P sorption capacity. The lower P recorded in the Itagunmodi soil (which had the highest clay content) may be due to its higher P sorption capacity. Clay particles had been observed to best correlate with sorbed P [19].

The present study was in a closed system without plants, so the mineralized P was not taken up by plants, hence the observed increase in available P. Poultry manure enhanced higher available P compared with tithonia compost probably due to its higher P content (1.31%) compared with tithonia (0.95%). Soil pH was positively correlated with available P; therefore the increases in soil P observed may be due to increase in P solubility which is favored by increase in soil pH. Due to its effect on microbial activity, soil pH influences plant residue decomposition processes. It also affects nutrient solubility and can change microbial community composition. Nutrient cycling is slowed or stopped if microbial populations are negatively affected [20].

Sanchez and Uehara [21] stated that the soil solution P concentration required for maximum plant growth differs with soil properties related to the diffusion of P to plant roots. It has been reported that phosphorus availability was differentially influenced by different P sources and different soils [22]. The magnitude of increase in P availability varied with the soil type and organic residue. It has been reported that the magnitude of increase in available P as a result of application of organic residues depended on the soil type, source of organic residue, time of sampling and rate of application [14]. Soil chemistry and physical conditions can also influence the rate of litter decomposition [23]. Decomposition of organic residues and subsequent nutrient release depend largely on residue quality and quantity, soil moisture and temperature and specific soil factors such as texture, mineralogy and acidity, biological activity and the presence of other nutrients [24].

Changes in soil nitrogen availability as a result of incubation of tithonia was less pronounced in Itagunmodi soil compared with Egbeda and Majeroku soils probably because of the higher clay content in Itagunmodi soil. Clay is one of the major soil texture components determining soil aeration and drainage and significantly affects residue decomposition rates. Clay concentration is positively correlated with aggregate size and aggregate formation and it was found to correlate negatively with potential N mineralization [25]. Rate of SOM decomposition increased as soil clay content decreased due to the decreased oxygen level in soils, and accumulation of SOM was positively correlated with soil clay concentration [26]. Odhiambo [27], reported that N release pattern of three legume residues followed a similar pattern in three soil types from south Africa in an incubation study. He also noted that high clay content in soil slowed down N mineralization. Immobilization of N as a result of incubation of organic residues in some of the soils is in line with the observation of Abbasi et al. [28]. Net N immobilization or mineralization from added organic residues has been reported to be influenced by such factors as biochemical composition of the organic residues, temperature, soil moisture and their interactions [29]. This may be the reason for the differences reported for changes in soil N with incubation of the organic residues in the different soils.

5. CONCLUSION

Nutrient release pattern of the residues varied with soil types and are dependent on soil characteristics that may influence nutrient use efficiency by crops. Poultry manure was more effective in increasing P availability in the soils than tithonia compost.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Hartemink AE. Soil fertility decline in the tropics with case study on plantations. ISRIC-CABI. Wallingford. 2003;360.
2. Dick WA, Gregorich EG. Developing and maintaining soil organic matter levels. In managing soil quality: Challenges in modern agriculture. (Schjonning P, et al. eds) CABI, Wallingford, UK. 2004;103–120.
3. FAO (Food and Agriculture Organization of United Nations). Organic matter; 2003.
   Available:http://www.fao.org/ag/ca/doc/Organic_matter.pdf
4. Angers DA, Caron J. Plant-induced changes in soil structure: Processes and feedbacks. Biogeochem. 1998;42:55-72.
5. Trinsoutrot I, Recous S, Mary B, Nicolardot B. C and N fluxes of decomposing 13C and 15N *Brassica napus* L.: Effects of residue composition and N content. Soil Biol. Biochem. 2000;32:1717-1730.
6. Corbels M, O'Connel AM, Grove TS, Mendham DS, Rance SJ. Nitrogen release from eucalypt leaves and legume residues as influenced by their biochemical quality and degree of contact with soil. Plant Soil. 2003;250:15-28.

7. Baggie I, Rowell DL, Robinson JS, Warren JP. Decomposition and phosphorus release from organic residues as affected residue quality and inorganic phosphorus. Agrofor. Syst. 2005;63:125-131.
8. Singh B, Rengel Z, Bowden JW. Canola residues decomposition: the effect of particle size on microbial respiration and cycling of sulphur in a sandy soil. Super Soil; 2004. Available:www.regional.au/au/asssi
9. Bahl GS, Toor GS. Influence of poultry manure on phosphorus availability and the standard phosphate requirement of crop estimated from quantity-intensity relationships in different soils. Bioresour. Techn. 2002;85:317-322.
10. Nziguheba G, Merckx R, Palm CA, Rao M. Organic residues affect phosphorus availability and maize yields in a Nitisol of western Kenya. Biol. Fertil. Soils. 2000;32: 328-339.
11. Hue NV. Effects of organic acids/anions on P sorption and phytoavailability in soils with different mineralogies. Soil Sci. 1991;152:463-471.
12. SAS Institute. SAS/STAT Users' Guide, SAS Institute, Cary, NC, USA; 2001.
13. Cong PT, Merckx R. Improving phosphorus availability in two upland soils of Vietnam using shape Tithonia diversifolia H. Plant Soil. 2005;269(1-2):11–23.
14. Opala PA, Okalebo JR, Othieno CO. Effects of organic and inorganic materials on soil acidity and phosphorus availability in a soil incubation study. International Scholarly Research Network ISRN Agronomy. 2012;10. DOI: 10.5402/2012/597216
15. Haynes RJ, Mokolobate MS. Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: A critical review of the phenomenon and the mechanisms involved. Nutr. Cycl. Agroecosyst. 2001;59:47–63.
16. Nziguheba G, Palm CA, Buresh RJ, Smithson PC. Soil phosphorus fractions and adsorption as affected by organic and inorganic sources. Plant Soil. 1998;198(2): 159–168.
17. Laboski CAM, Lamb JA. Changes in soil test phosphorus concentration after application of manure or fertilizer. Soil Sci. Soc. Amer. J. 2003;67(2):544–554.
18. Spychaj-Fabisiak E, Dlugosz J, Zamorski R. The effect of the phosphorus dosage and incubation time on the process of retarding available phosphorus forms in a sandy soil. Polish J. Soil Sci. 2005;38(1): 23–30.
19. Olatunji OO, Oyediran GO, Kolawole GO, Obi JC, Ige DVand Akinremi OO. Phosphate sorption capacity of some tropical soils on basement complex of south western Nigeria. Int. J. Cur. Res. 2012;4(4):017–020.
20. Bolan NS, Hedley MJ. Role of carbon, nitrogen and sulfur cycles in soil acidification. In 'Handbook of Soil Acidity'. (Ed. Rengel Z) (Mercel Dekker AG: New York, USA). 2003;29-55.
21. Sanchez PA, Uehara G. Management considerations for acid soils with high phosphorus fixation capacity. *In*: Khasawneh FE, et al. (eds) Proc on the role of phosphorus in agriculture, June 1-3 1976. ASA CSSA and SSSA Madison, WI, USA. 1980;471-513.
22. Torres-Dorante LO, Norbert C, Bernd S, Hans-Werner O. Fertilizer-use efficiency of different inorganic polyphosphate sources: Effects on soil P availability and plant P acquisition during early growth of corn. J. Plt. Nutr. Soil Sci. 2006;169(4):509-515.
23. Liu P, Huang J, Han X, Sun OJ, Zhou Z. Differential responses of litter decomposition to increased soil nutrients and water between two contrasting grassland plant species of Inner Mongolia, China. Appl. Soil Ecol. 2006;34:266–275.
24. Myers RJK, Palm CA, Cuevas E, Gunatilleke IUN, Brossard M. The synchronization of nutrient mineralization and plant nutrient demand. In: Woomer PL, Swift MJ, (eds). The biological manage-ment of tropical soil fertility. Wiley-Sayce Publishers, Chichester, UK. 1994;81–116.
25. Sylvia DM, Hartel PG, Furhmann JJ, Zuberer DA. Principles and applications of soil microbiology. 2nd Edn, Prentice Hall Inc., Upper Saddle River, New Jersey; 2005.
26. Epstein HE, Burke IC, Lauenroth WK. Regional patterns of decomposition and primary production rates in the US Great Plains. Ecolog. Soc. Amer. 2002;83:320-327.
27. Odhiambo JJO. Decomposition and nitrogen release by green manure legume residues in different soil types. Afr. J. Agric. Res. 2010;5(1):090–096.

28. Abbasi MK, Tahir MM, Sabir N, Khurshid M. Impact of the addition of different plant residues on nitrogen mineralization–Immobilization turnover and carbon content of a soil incubated under laboratory conditions. Solid Earth. 2015;6:197–205.

29. Abera G, Wolde-meskel E, Bakken LR. Carbon and nitrogen mineralization dynamics in different soils of the tropics amended with legume residues and contrasting soil moisture contents. Biol. and Fertil. Soils. 2012;48:51–66.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14286