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Transformation of Different Fractions of N and P in Soil

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A laboratory experiment was conducted to monitor the changes in different forms of inorganic and organic N and P in an alluvial and an acidic soil fertilized with inorganic N and P either alone or in combination. Results revealed that in both the soils exchangeable NH_4^+ and soluble NO_3^- decreased with increase in the period of investigation. Irrespective of soils, addition of inorganic N alone causes faster rate of N loss from the soil than combined application of N and P fertilizers. Combined application of N and P fertilizers accentuates mineralization process of hydrolysable NH_4^+ and amino acid-N fractions particularly, in acidic Jhargram soil. Irrespective of soils, the highest amount of decrease in active P (saloid-P + Al-P + Fe-P + Ca-P) was recorded in the treatment fertilized with inorganic P alone. Higher amount of decrease in organic P was recorded in alluvial Mohanpur soil than that of acidic Jhargram soil treated with inorganic P alone.

Key words: Acid soil, Organic N, Organic P, Active P

N and P are the major nutrients required by plants for growth and metabolic activities and are mostly taken up from the soil. Both N and P present in soil generally comes from natural and applied fertilizers. The amount of N and P supplied during a cropping season is influenced by many factors. Environmental conditions as well as management practices change the liberation process and also quantity of soil N and P to be released from its organic form for plant utilization.

A bulk of total nitrogen is present in organic form and only about 2 per cent in inorganic form, except where large quantities of inorganic nitrogen fertilizers have been added. The organic form of N, particularly the hydrolysable form, is slowly mineralized and is transformed to mineral N. As it is well established that native soil N-transformation is different from that of fertilizer N, it is necessary to understand the N-transformation process, which ultimately influences the N-uptake by plants.

Phosphorus is a vital component of the substances that are building blocks of genes and chromosomes. It plays an important role in virtually every plant process that involves energy transfer. It has already been established that quantity of total P has little or no relationship to the availability of P to plants. Thus understanding the relationship between various forms of P, their interactions in soils and various factors influencing P availability to plants is essential for efficient P management in soil. According to Chang and Jackson (1957) phosphorus bound to Al (Al-P), Fe (Fe-P) and Ca (Ca-P) constitutes the major active forms of inorganic P and are most available to plants. Another highly available form of P is the saloid bound 'P' defined by Peterson and Corey (1966). Organic phosphorus, which constitutes a substantial portion, of 21 to 74 per cent (Omotoso, 1971) of total soil phosphorus, mainly accumulates in soil from plant, bacterial, fungal and animal residues.

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Application of N-fertilizer may influence the P transformation processes in soil. On the other hand, P-fertilization may also affect the transformation processes of different inorganic and organic forms of N in soils. However, very little investigations were carried out in this regard to the understand the relation ship among different forms of inorganic and organic N and P in soils fertilized with or without N and P fertilizers either alone or in combination.

Materials and Methods

Soil collection

Soils (0-15 cm) used for the present investigation were composite samples collected from the cultivated fields Instructional farm at Mohanpur in the district of Nadia and Jhargram farm in the district of West Midnapur that belongs to Bidhan Chandra Agricultural University in West Bengal, India. Before use, soils were air dried, ground and passed through 80 mesh sieve.

The physical and chemical properties of both the soils are presented in Table 1.

Experimental set up

Fifteen gram each of air dried soil samples were taken in 100ml beakers for the incubation study. There were four treatments replicated thrice. The 1st treatment was control without addition of any inorganic N and P fertilizer. In the 2nd treatment, inorganic N was added at 100 mg kg^{-1} N in the form of ammonium sulphate ($(NH_4)_2SO_4$). In the 3rd treatment, P was added as treatment material at 50 mg kg^{-1} P_2O_5 as Single Super Phosphate (SSP). The 4th treatment was both inorganic N and P added at 100 mg kg^{-1} and 50 mg kg^{-1} in the form of $(NH_4)_2SO_4$ and SSP, respectively. All the treatment combinations were replicated thrice. Respective soil samples were moistened to 60 per cent of the Moisture Holding Capacity (MHC) by the addition of distilled water. After moistening, the soils were maintained at room temperature (30 ± 2 ^{0}C) for a period of 105 days. Five separate sets were maintained for laboratory analysis on 0, 15, 45, 75 and 105th day of incubation. Samples were collected on respective days for analysis of different fractions of N and P. Loss of moisture due to evaporation was replenished by the addition of distilled water on every alternate day by assessing the difference in weight.

Methods followed

Exchangeable NH_4^+ and soluble NO_3^- were determined according to the method of Bremner and Keeney (1966). Among the different fractions of organic N, total hydrolysable organic N, hydrolysable NH_4^+ and amino acid-N, which are most susceptible to mineralization, were determined by the method of Stevenson (1996). Available phosphorus was determined using Bray and Kurtz extractant for the Jhargram soil and Olsen extractant for Mohanpur soil following the method of Jackson (1967). Fractions of soil P were determined according to the method of Chang and Jackson (1957). Saloid P was estimated by the method of Peterson and Corey (1966). Organic P was determined following the method of Jackson (1967). Total active P which is presented in the text is computed by adding Al-P. Fe-P, Ca-P and Saloid-P following the method of Prasad and Power (1997).

Results and Discussion

Irrespective of soils and treatments, the amount of exchangeable NH_4^+ decreased with increase in the period of incubation (Table 2). The decrease in exchangeable NH_4^+ with time might be due to its conversion to NO_3^- form or loss through denitrification (Groffman et al., 1987) and/or volatilization (Freney and Black, 1988). Irrespective of soils, addition of only inorganic N fertilizer resulted in a greater decrease in exchangeable NH_4^+-N (56.71 mg kg^{-1}) for Mohanpur and Jhargram soil (69.47 mg kg^{-1}) . In the absence of both N and P fertilizers the decrease in exchangeable NH_4^+-N amounted to 51.21 and 30.74 mg kg^{-1} for Mohanpur and Jhargram soil, respectively. The results in Table 2 clearly pointed out that irrespective of soils, addition of inorganic N alone causes faster rate of N loss from the soil, than combined application of N and P fertilizers because of the priming effect of N-fertilization (Saha and Mukhopadhyay, 1984). The results also showed that addition of inorganic P fertilizer slowed down the N-mineralisation rate. This is perhaps due to the decrease in activities of ammonifying bacteria in the presence of added inorganic P (Kitayama, 1996). Duncan's statistical test of the results in Table 2 also reveal that, irrespective of sampling days, addition of inorganic N either alone or in combination with inorganic P fertilizer significantly affect exchangeable NH_4^+-N in both the Mohanpur and Jhargram soils.

Irrespective of soils and treatments, the amount of soluble NO_3^--N (Table 3) decreased with increase in the period of investigation. The amount of decrease was more pronounced in Mohanpur than that of Jhargram soil because of the variation in

Table 1. Physical and chemical characteristics of the soils used for the investigation

Sl. No.	Analysis done	Mohanpur soil	Jhargram soil	Methods adopted
1.	pH (soil:water :: 1:2.5)	7.75	5.30	Glass electrode pH meter, Black, 1965
2.	EC (dsm^{-1})	0.44	0.18	Electrical conductivity bridge, Black, 1965
3.	Mechanical analysis Sand (%)	25.2	62.1	Hydrometer method (Bouyoucos, 1962)
	Silt (%)	30.0	15.7	
	Clay (%)	44.8	22.2	
4.	Oxidisable organic carbon (%)	0.60	0.22	Walkley and Black method, Jackson, 1967
5.	A. Exchangeable NH_4^+ (mg kg^{-1})	82.32	78.30	Stevenson, 1998
	B. Soluble NO_3(mg kg^{-1})	115.24	65.86	Bremner and Keeney, 1966
	C.Organic forms of N(mg kg^{-1})			Stevenson, 1996
	i. Hydrolysable NH_4-N	264.93	252.58	
	ii. Amino acid-N	328.74	302.49	
6.	CEC [C mol (P^+) kg^{-1}]	28.1	10.9	Schollenberger and Simon method (Jackson, 1967)
7.	Moisture holding capacity (%)	50.0	42.04	Keen-Rack Zowski method (Piper, 1950)
8.	A. Available P (mg kg^{-1})	15.83	18.77	Olsen,1954
	B. Different forms of inorganic P			
	a) Saloid P (mg kg^{-1})	4.20	3.00	Peterson and Corey, 1966
	b)Al-P (mg kg^{-1})	19.80	28.83	Chang and Jackson, 1957
	c) Fe-P (mg kg^{-1})	46.45	66.95	Chang and Jackson, 1957
	d) Ca P (mg kg^{-1})	13.37	16.60	Chang and Jackson, 1957
	e) Active-P (mg kg^{-1})	83.82	115.3	Chang and Jackson, 1957
	C. Organic -P (mg kg^{-1})	105.80	884.33	Chang and Jackson, 1957
9.	Nomenclature according to USDA soil classification	Typic Fluvaquent	Plinth Ustalf	USDA

Table 2. Changes in the amount (mg kg^{-1}) of exchangeable NH_4^+ in soils treated with or without inorganic N and P either alone or in combination

Treatments	Soils	Incubation period (days) 0	15	45	75	105
Soil	S_1	82.32^{c}	47.56^{b}	42.07^{b}	36.60^{b}	31.11^{b}
	S_2	78.30^{r}	73.17^{q}	71.34^{q}	56.71^{q}	47.56^{q}
Soil + N	S_1	137.20^{a}	89.64^{a}	87.81^{a}	84.15^{a}	80.49^{a}
	S_2	128.92^{p}	98.79^{p}	90.55^{p}	73.17^{p}	59.45^{p}
Soil + P	S_1	82.32^{c}	54.88^{b}	49.39^{b}	40.26^{b}	40.24^{b}
	S_2	77.59^{r}	65.86^{q}	62.20^{q}	60.37^{q}	42.99^{q}
Soil + N + P	S_1	109.76^{b}	76.83^{a}	75.01^{a}	75.00^{a}	69.51^{a}
	S_2	106.12^{q}	96.90^{p}	96.04^{p}	95.12^{p}	87.81^{p}
LSD(P=0.05)				Within soils		
	S_1	2.85	16.06	19.10	18.87	24.96
	S_2	16.69	18.39	15.78	27.34	30.57
				Between soils		
	Soils	NS	7.94	8.05	10.80	NS
	Treatments	7.78	11.22	11.39	15.27	18.14

S_1 = Mohanpur Soil ; S_2 =Jhargram Soil; (a,b,c,d) and (p,q,r,s) define Duncan's results for Mohanpur and Jhargram soil respectively.

total N content of the respective soil under investigation. The results also clearly state that absence of N and P or presence of N alone or in combination with P did not affect the NO_3^- accumulation process to a great extent in both the soils.

Table 3. Changes in the amount (mg kg^{-1}) of soluble NO_3^- in soils treated with or without inorganic N and P either alone or in combination

Treatments	Soils	Incubation period (days) 0	15	45	75	105
Soil	S_1	115.24^{b}	53.05^{b}	51.22^{b}	49.39^{b}	43.90^{b}
	S_2	65.86^{r}	57.88^{q}	56.71^{q}	46.65^{q}	42.08^{q}
Soil + N	S_1	159.15^{a}	104.32^{a}	102.44^{a}	102.44^{a}	95.13^{a}
	S_2	109.76^{p}	93.30^{p}	89.64^{p}	84.82^{p}	80.49^{p}
Soil + P	S_1	115.24^{b}	54.88^{b}	49.39^{b}	43.90^{b}	40.25^{b}
	S_2	76.83^{q}	60.37^{q}	56.71^{q}	47.56^{q}	31.10^{q}
Soil + N + P	S_1	136.68^{a}	89.64^{a}	82.32^{a}	65.86^{a}	54.88^{a}
	S_2	96.04^{q}	78.66^{p}	76.83^{p}	71.34^{p}	69.52^{p}
LSD(P=0.05)				Within soils		
	S_1	22.48	25.66	24.05	30.71	32.54
	S_2	28.94	17.40	22.98	18.96	13.99
				Between soils		
	Soils	11.91	NS	NS	NS	NS
	Treatments	16.84	14.25	15.29	16.59	16.28

S_1 = Mohanpur Soil ; S_2 =Jhargram Soil; (a,b,c,d) and (p,q,r,s) define Duncan's results for Mohanpur and Jhargram soil respectively.

Data in Table 4 revealed that highest amount of decrease in hydrolysable NH_4^+-N was recorded in Mohanpur soil treated with inorganic N alone. However, in case of Jhargram soil, the intensity of decrease in hydrolysable NH_4^+-N is the highest in the treatment where, both N and P fertilizers had

Table 4. Changes in the amount (mg kg^{-1}) of hydrolysable- NH_4^+-N in soils treated with or without inorganic N and P either alone or in combination

Treatments	Soils	Incubation period (days) 0	15	45	75	105
Soil	S_1	264.93^{c}	258.30^{b}	242.63^{b}	241.58^{b}	229.56^{b}
	S_2	252.58^{r}	251.1^{q}	243.08^{q}	238.13^{q}	226.96^{q}
Soil + N	S_1	285.20^{a}	277.22^{a}	264.50^{a}	257.05^{a}	240.75^{b}
	S_2	274.96^{p}	270.08^{p}	262.67^{p}	254.42^{p}	254.41^{p}
Soil + P	S_1	254.26^{d}	250.88^{b}	243.60^{b}	233.11^{c}	225.86^{c}
	S_2	242.22^{s}	240.70^{s}	230.61^{r}	222.82^{r}	217.60^{q}
Soil + N + P	S_1	272.34^{b}	268.24^{a}	262.13^{a}	254.24^{a}	255.91^{a}
	S_2	265.41^{q}	258.23^{q}	243.46^{q}	241.01^{q}	227.41^{q}
LSD(P=0.05)				Within soils		
	S_1	2.14	12.21	10.86	8.10	14.08
	S_2	2.19	2.84	8.91	6.77	13.50
				Between soils		
	Soils	0.99	4.07	3.79	3.43	6.34
	Treatments	1.41	5.76	5.36	4.85	6.89

S_1 = Mohanpur Soil ; S_2 =Jhargram Soil; (a,b,c,d) and (p,q,r,s) define Duncan's results for Mohanpur and Jhargram soil respectively.

been included. The results thus, clearly pointed out that addition of inorganic N and P fertilizers influenced the mineralization pattern of hydrolysable NH_4^+-N. The results are in conformity with the Duncan's statistical test.

Results in Table 5 revealed that irrespective of days of sampling, comparatively higher amount of amino acid N is accumulated in Mohanpur than Jhargram soil. Mineralization pattern of amino acid N is different from that of hydrolysable NH_4^+-N

Table 5. Changes in the amount (mg Kg^{-1}) of Amino acid- N in soils treated with or without inorganic N and P either alone or in combination

Treatment	Soils	Incubation period (days)				
		0	15	45	75	105
Soil	S_1	328.74^{a}	317.76^{b}	302.79^{b}	295.37^{b}	293.82^{b}
	S_2	302.49^{q}	296.83^{q}	291.48^{q}	290.24^{p}	286.27^{p}
Soil + N	S_1	349.09^{a}	340.42^{a}	332.75^{a}	325.09^{a}	324.77^{a}
	S_2	336.20^{p}	336.12^{p}	328.86^{q}	219.93^{s}	213.49^{r}
Soil + P	S_1	310.94^{a}	300.02^{d}	299.41^{c}	294.29^{b}	292.65^{b}
	S_2	286.74^{s}	266.50^{r}	255.70^{s}	247.15^{r}	242.24^{q}
Soil + N + P	S_1	316.37^{a}	307.88^{c}	300.09^{b}	295.82^{b}	290.94^{b}
	S_2	294.83^{r}	288.13^{q}	272.78^{r}	262.66^{q}	248.90^{q}
LSD(P=0.05)				Within Soils		
	S_1	NS	5.50	3.81	10.26	7.28
	S_2	1.74	10.31	4.23	7.74	11.99
				Between Soils		
	Soils	NS	3.80	2.13	4.18	4.56
	Treatments	NS	5.37	3.02	5.91	6.45

S_1 = Mohanpur Soil ; S_2 =Jhargram Soil; (a,b,c,d) and (p,q,r,s) define Duncan's results for Mohanpur and Jhargram soil respectively.

fraction. It is important to mention that both the hydrolysable NH_4^+-N and amino acid- N fractions of organic N are highly susceptible to mineralization in presence of both the inorganic N and P fertilizers particularly, in Jhargram soil, which is acidic in reaction. This is perhaps because of fixation of added inorganic P by Fe and Al present in acid soil forming Fe and Al-phosphates, respectively. Duncan statistical test reveal that changes in the amount of amino acid N did not behave in a similar way as was found for other inorganic and organic forms of N. Addition of inorganic P encouraged conversion of available P to other forms. The lowest amount of decrease in available P (Table 6) was recorded in both the soils, in the treatment which received combined application of inorganic N and P. This is due to interaction effect (Kitayama, 1996). Duncan's results revealed that addition of inorganic P alone as treatment significantly influences the changes in the amount of available P in Mohanpur soil throughout the experimentation period.

Table 6. Changes in the amount (mg kg^{-1}) of Available- P in soils treated with or without inorganic N and P either alone or in combination

Treatments	Soils	Incubation period (days)				
		0	15	45	75	105
Soil	S_1	15.83^{d}	14.40^{c}	13.13^{c}	12.27^{b}	11.13^{b}
	S_2	18.70^{q}	18.45^{q}	17.17^{q}	16.87^{r}	16.37^{r}
Soil + N	S_1	14.33^{c}	12.97^{c}	12.80^{c}	11.60^{b}	10.40^{b}
	S_2	18.70^{q}	18.03^{p}	17.93^{q}	17.37^{r}	16.60^{r}
Soil + P	S_1	28.23^{a}	28.00^{a}	25.13^{a}	21.27^{a}	21.03^{a}
	S_2	29.50^{p}	28.23^{p}	27.03^{p}	25.93^{q}	26.13^{q}
Soil + N + P	S_1	24.00^{b}	22.43^{b}	20.90^{b}	20.73^{a}	20.10^{a}
	S_2	29.88^{p}	29.75^{p}	29.73^{p}	29.17^{p}	28.83^{p}
LSD(P=0.05)				Within soils		
	S_1	1.42	2.33	1.89	1.72	2.55
	S_2	1.81	2.16	2.02	2.02	2.45
				Between soils		
	Soils	0.75	1.03	0.90	0.86	1.15
	Treatments	1.06	1.46	1.27	1.22	1.63

S_1 = Mohanpur Soil ; S_2 =Jhargram Soil; (a,b,c,d) and (p,q,r,s) define Duncan's results for Mohanpur and Jhargram soil respectively.

Irrespective of soils, the highest amount of decrease in active P (Saloid- P + Al-P + Fe-P + Ca-P) was recorded on 105th over 0th day of investigation where, addition of inorganic P alone was done (Table 7). Again, irrespective of treatments and sampling days, comparatively higher amount of active P is

Table 7. Changes in the amount (mg kg $^{-1}$) of active-P in soils treated with or without inorganic N and P either alone or in combination

Treatments	Soils	Incubation period (days)				
		0	15	45	75	105
Soil	S_1	83.82^c	80.26^c	75.43^c	69.02^c	66.67^b
	S_2	115.38^r	112.12^q	108.81^q	112.26^q	111.96^q
Soil + N	S_1	81.62^c	75.50^d	72.83^c	74.42^c	65.44^b
	S_2	111.43^s	109.85^q	107.57^q	109.49^q	109.04^q
Soil + P	S_1	125.53^a	118.27^a	112.29^a	108.34^a	101.44^a
	S_2	158.08^p	150.67^p	148.44^q	147.30^p	145.36^p
Soil + N + P	S_1	113.27^b	105.60^b	101.44^b	96.54^b	99.24^a
	S_2	153.03^q	150.84^p	147.08^p	143.06^p	145.20^p
LSD(P=0.05)		Within soils				
	S_1	4.18	3.87	5.52	10.68	8.81
	S_2	3.09	6.40	5.28	5.91	5.67
		Between soils				
	Soils	1.69	2.43	2.48	3.97	3.40
	Treatments	2.39	3.44	3.51	5.61	4.81

S_1 = Mohanpur Soil ; S_2 =Jhargram Soil; (a,b,c,d) and (p,q,r,s) define Duncan's results for Mohanpur and Jhargram soil respectively.

accumulated in Jhargram over that of Mohanpur soil. Thus it is clear from the results that the amount of active P in the soil is not the only factor but also the physical and chemical properties of soil is of great concern for transformation of this fraction of inorganic P in a soil system (Zhao *et. al,* 2010). Duncan test reveals that addition of inorganic P fertilizer alone significantly influences the changes in active P over the whole experimentation period in both the soils under study. Furthermore, it is shown that the addition of both N and P fertilizer also significantly affected the transformation process of active P in Jhargram but not in Mohanpur soil. This is due to presence of higher amount of active P in Jhargram soil.

Comparatively higher amount of decrease in organic P was recorded in Mohanpur than that of Jhargram soil treated with inorganic P alone (Table 8). Addition of inorganic P alone increased the

Table 8. Changes in the amount (mg kg^{-1}) of organic P in soils treated with or without inorganic N and P either alone or in combination

Treatments	Soils	Incubation period (days)				
		0	15	45	75	105
Soil	S_1	105.80^c	104.90^b	103.17^b	102.10^b	101.87^b
	S_2	84.33^r	84.10^r	83.73^r	83.67^q	83.33^q
Soil + N	S_1	104.80^c	104.77^b	103.47^b	101.63^b	98.75^b
	S_2	80.83^s	81.00^r	81.03^r	81.00^r	80.83^r
Soil + P	S_1	132.27^a	126.50^a	102.73^b	99.57^b	99.53^b
	S_2	102.35^p	101.83^p	101.73^p	99.83^p	99.53^p
Soil + N + P	S_1	124.95^b	125.77^a	128.00^a	131.27^a	136.97^a
	S_2	90.40^q	96.37^q	96.37^q	98.43^p	99.60^p
LSD(P=0.05)		Within soils				
	S_1	7.02	8.97	8.55	4.92	5.30
	S_2	1.78	4.13	3.77	2.54	1.87
		Between soils				
	Soils	2.35	3.21	3.04	1.80	1.83
	Treatments	3.33	4.54	4.29	2.55	2.58

S_1 = Mohanpur Soil ; S_2 =Jhargram Soil; (a,b,c,d) and (p,q,r,s) define Duncan's results for Mohanpur and Jhargram soil respectively.

organic P content due to temporary tying up of the P by microorganisms. Prasad and Power (1997) also found that the rate of organic P mineralization is of lower order in acidic soils. Data in Table 8 further reveal that combined addition of inorganic N and P showed a completely reverse trend of results in both the soils. Addition of inorganic N and P makes a balanced nutrition for growth and activities of microorganisms resulting higher amount of immobilization of inorganic P in both the soils (Powell *et. al,* 1999). Results of the Duncan's test revealed that addition of inorganic P alone, significantly influence the changes in the amount of organic P in Jhargram soil but not to that extent in

Mohanpur soil particularly, at the later stage of incubation.

Conclusion

Combined application of inorganic N and P helps to retain comparatively higher amount of N in available form in soils. This is due to faster rate of N mineralization of organic N. Application of inorganic P decreased active P content in soil. The content of organic P in a particular soil plays an important role with respect to its mineralization.

References

Black, C.A. 1965. *Methods of soil analysis*. Part-II. Agron. Ser. No. 9. Am. Soc. Agron. Inc., Madison, Wisconsin, USA.

Bouyoucus, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. *Agron. J.* **54**: 464-465.

Bremner, J.M and Keeney, D.R. 1966. Determination of exchangeable ammonium nitrate and nitrite by extraction distillation methods. *Soil Sci. Soc. Am. Proc*. **30**: 577-587.

Chang, S.C. and Jackson, M.L. 1957. Fractionation of soil phosphorus. *Soil Sci*. **84:** 133–144.

Freney, J.R. and A.S. Black. 1988. Importance of ammonia volatilization as a loss process. In: Advances in Nitrogen cycling in Agricultural Ecosystem. J.R. Wilson (ed.) CAB International Wallingford, pp. 156-173.

Groffman, P.M., Tiedje, J.M., Robertson, G.P. and Christensen, S. 1987. De-nitrification at different temporal and geographical scales: proximal and distal controls. In: Wilson JR (ed) Advances in nitrogen cycling in agricultural ecosystems. CAB International, Oxon, pp 174–192.

Jackson, M.L. 1967. *"Soil Chemical Analysis"*. Prentice Hall of India Private Ltd. New Delhi.

Kitayama, K. 1996. Soil N dynamics along a gradient of long term soil development in a Hawailan Wet montane rain forest. *Plant and Soil.* **183:** 253-262.

Omotoso, F.I. 1971. Organic phosphorus contents of some cocoa growing soils of southern Nigeria. *Soil Sci*. **112:** 195-199.

Peterson, G.W. and Corey, R.B. 1966. A modified Chang and Jackson procedure for routine fractionation of inorganic soil properties. *Soil. Sci. Soc. Am. Proc.* **30:** 563-565.

Piper, C.S. 1950. *Soil and Plant Analysis*. Inter Science Publishers Inc., New York.

Powell, J.M., Ikpe, F.N. and Somda, Z.C. 1999. Crop yield and the fate of N and P following application of plant materials and feces to soil. *Nutrient cycling in Agrosystems.* **54:** 215-226.

Prasad, R. and Power, J.F. 1997. Soil fertility management for sustainable agriculture. CRC press LLC Lewis Publishers, Boca Raton, New York, USA

Saha, D. and Mukhopadhyay, A.K. 1984. N-transformation in soil plant system in a field experiment on a high ammonium fixing alluvial soil. *Indian Agric.* **28(4):** 231-235.

Stevenson, F.J. 1996. Nitrogen – organic forms. *In: "*Methods of soil analysis, *Part 3 – Chemical methods (Eds DL Sparks et al)* pp 1185-1200 (SSSA and ASA Madison, WI)

Zhao, Q., Zeng, D.H. and Fan, Z.P. 2010. Nitrogen and phosphorus transformations in the rhizospheres of three tree species in a nutrient-poor sandy soil. *Applied Soil Ecology* **46:** 341–346

Olsen, S.R., Cole, C.V., Watnabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. Agric. Circ. 939.

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