Nigerian Journal of Soil Science

journal homepage:www.soilsjournalnigeria.com

EFFECT OF PHOSPHATE ROCK ADDITION ON SOIL ORGANIC MATTER

[1] O.O. Adesanwo; [2] M.T. Adetunji and [3]S. Diatta

[1]*Department of Soil Science & Land Resources Management, Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife*

[2]*Department of Soil Science and Land Management, Federal University of Agriculture, Abeokuta.*

[3]*African Rice Center, International Institute of Tropical Agriculture*

ABSTRACT

The fertilizer treatments consisted of four rates of Ogun phosphate rock (0, 30, 60 and 90 kg P ha^{-1}) and triple super-phosphate at 40 kg P ha^{-1}. Legume treatment consisted of *Mucuna* and cowpea and were planted as pre-rice crop. Soil samples were collected and analyzed for organic carbon. Four pellets of Ogun phosphorites labeled OG1, OG2, OG3 and OG4 was randomly selected and subjected to X- ray fluorescence analysis, the mixture of different pellets used for the experiment was also analysed. Loss on ignition from the different pellets and the mixture was recorded. Organic carbon content of the raw phosphate rock was determined too. Results showed the Loss on ignition which represent combination of moisture and CO_2 varied from 11.67 – 16.27%organic carbon content of Ogun phosphate rock (0.31%) was higher than other phosphate rock materials, Sokoto (0.12%) and Togo (0.12%). There was significant increase in organic carbon as a result of Ogun phosphate rock addition ($p< 0.05$) in the greenhouse with soil samples from Ibadan but no significant effect was observed with samples from other two sites, but gradual increase was noticed. Increases of 8.2%, 12.5% and 14.8% in organic carbon was recorded for OPR applied at 30, 60 and 90 kgha^{-1} respectively over control pot for soil sample from Abeokuta without incorporation of legume.

Keywords: Phosphate rock, soil organic matter, carbon sequestration

INTRODUCTION

Climate change is a serious challenge to humanity and sustainable development. It is a great threat to Earth’s biodiversity, natural resources and Agriculture. Increase in soil organic matter has been discovered to reduce global warming through carbon sequestration, additional 1.6% in organic matter on the top soil would bring CO_2 concentration below 300 ppm (Allan Yeoman, 2005, 2007) Soil carbon sequestration is the process of transferring carbon dioxide from the atmosphere into the soil through crop residues and other organic solids, and in a form that is not immediately reemitted. This transfer of carbon helps off-set emissions from fossil fuel combustion and other carbon-emitting activities while enhancing soil quality and long-term agronomic productivity.

Modern agricultural practices introduce a variety of unwanted contaminants to soils that represent a potential threat to human and ecological health depending on their toxicity and bioavailability to crops and foraging animals. Poor management of Nigeria's environment is costing the nation roughly $5 billion annually, much of the damage resulted from oil and gas extraction in the Niger Delta region, poor agricultural practices, oil exploration, oil spills, grazing and habitat destruction. (Aminu-Kano, 2009). Mineral sequestration is an artificial process which aims to trap carbon in the form of solid carbonate salts though the process is slow in nature but is responsible for the deposition and accumulation of carbon-rich geological minerals like limestone, apatite etc so carbon can be sequestered artificially (i.e. not using the natural processes of the carbon cycle) by first capturing it or delay from being released into the atmosphere. It can be passively stored *or* remain productively utilized over time in a variety of ways. One of which is addition of phosphate material to supplement plant nutrients. Extensive deposits of phosphate rock (PR) have been identified in four sedimentary basins in Nigeria. The deposits are found in Sokoto, Ogun, Imo and Delta states. Sokoto and Ogun phosphate PR were used in several agronomic studies on a variety of soils in Nigeria to test its efficiency as an alternative phosphorus source for crop production (Adediran and Sobulo, 1998; Akande *et al.*, 1998, Adesanwo *et al;* 2010) but no information yet concerning its use in improving the carbon sink of soils. Therefore, the objective of this project was to affirm if addition of phosphate rock material will increase soil organic carbon content.

Objective

To determine the effect of phosphate rock addition on soil organic matter with and without legume biomass

MATERIALS AND METHODS

Greenhouse and Field experiments were conducted to monitor the effect of addition of OPR on soil organic matter.

Description of Experimental sites

Ibadan: The study site at the International Institute of Tropical Agriculture was located at latitude 7^o 30’N and longitude 3^o 54’E. The soil is classified as Egbeda series (Oxic Kandiustalf) derived from the basement complex rocks described by Moorman *et al*., (1985). The second soil sampling location was at the Institute of Agricultural Research and Training (latitude 6^o 54^1 N and longitude 3^o 42^1 E). The soil is well-drained loam sand underlain by sedimentary rock. The soils are Oxic Kandiustalf according to USDA taxonomy and Nitosols according to FAO /UNESCO classification (FAO/UNESCO, 1990). The third soil sampling location is the University of Agriculture located between latitude 7^o 15^1 N and longitude 3^0 35^1 E in Abeokuta. It overlies the Precambrian metamorphic rocks of the basement complex (Jones and Hockey, 1964) in South Western Nigeria. The soil is classified as Typic Paleudalf (Soil Survey Staff, 1975; Agboola and Ogunkunle, 1993)

Greenhouse Experiment

The experiment was carried out in the greenhouse of the International Institute of Tropical Agriculture (IITA) Ibadan. 1 kg of air-dried, sieved (2 mm) soil samples from the three experimental sites (Ibadan, Ikenne and Abeokuta) were uniformly mixed with Ogun phosphate rock at four rates (0, 30, 60 and 90 kg P ha^{-1}) and one rate of triple super phosphate (40 kg ha^{-1}) in a 2 kg plastic pots. It was a factorial experiment arranged in a Complete Randomized Block design replicated three times. *Mucuna* and cowpea seeds were planted for six weeks as pre-rice crop, after which the above ground plant material of each pot was cut into small pieces, thoroughly mixed with soil and left for four weeks to decompose before planting rice (NERICA-1). Four rice seeds were planted directly and later trimmed down to two after two weeks. All pots received basal application of N at 60 kg ha^{-1} and muriate of potash at 30 kg ha^{-1}. The experiment was terminated at the nine weeks after planting. Soil samples were taken and analyzed for pH in water and organic carbon.

Field Experiment

The field experiments were conducted at three sites Ibadan (IITA), Ikenne (IAR&T) and Abeokuta (UNAAB) between 2003–2005. The treatments were five rates of phosphorus from two sources (OPR at 0, 30, 60 and 90 kg P ha^{-1} and TSP at 40 kg ha^{-1}) and two legume crops *Mucuna* and cowpea (IT98K – 356-1). It was a factorial experiment arranged in split plot design with legume as the main plot and P fertilizer rates as the sub-plot and replicated three times. Two seeds of *Mucuna* and four seeds of cowpea were sown at a spacing of 25 cm by 50 cm and the crops grown to maturity as pre- rice crop in 2003. Cowpea seeds were harvested in 2004 and the biomass of both legumes remained on the field. The OPR was ground and sieved through 0.1mm sieve, broadcast and immediately mixed with legume biomass mechanically. Triple Super Phosphate (TSP) at 40 kg P ha^{-1} was applied after planting rice (NERICA - 1). Six seeds of rice were dribbled along the rows at spacing of 25cm by 25 cm. Pre – emergence herbicide, Ronstar was used to control weeds. In addition, plots were hand weeded at 4 and 8 weeks after emergence of the crop. All the treatment plots received basal 60 kg ha^{-1} as urea which was applied in three split doses (1/2 after planting, ¼ at tillering and ¼ at booting stages of rice crop). Harvesting was done and grain yield per plot at 14 % moisture was taken. The experiment was repeated to determine residual effect of applied phosphate rock on soil organic carbon.

Laboratory Analysis

Soil samples collected from the experimental sites (Ibadan, Ikenne and Abeokuta) were dried, sieved using 2 mm sieve and subjected to physical and chemical analysis. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1962) using sodium hexameta-phosphate as the dispersing agent. Soil pH was determined in distilled water (1:1 soil water ratio) with a pH meter. Exchangeable cations (K, Ca, Na, and Mg) were determined by extraction with neutral, normal NH_4OAc at soil solution ratio 1:10. Ca and Mg in the extract were determined by Atomic absorption spectrophotometer and Na and K by flame photometer. Soil exchangeable acidity was determined by 1M KCl extraction and 0.01M NaOH titration. (Mclean, 1982). Cation exchange capacity (CEC) was obtained by summation of exchangeable cations (K, Ca and Mg) and exchange acidity. Available P was determined using 0.03N NH_4F in 0.025N HCl as extractant (Bray and Kurtz, 1945) and P in the extract was analyzed colorimetrically by the molybdenum blue method at 636 nm. Soil organic carbon (using soil samples sieved through 1mm sieve) was determined by wet oxidation with sulphuric acid (Walkey and Black, 1934). Free Fe and Al oxides were extracted by citrate dithionite bi-carbonate method (Mehra and Jackson, 1960), extractable Fe and Al by 0.3 M $(NH_4)_2C_2O_4$ (Saunders, 1965), Fe and Al in the extract was determined with atomic absorption spectrophotometry.

Characterization studies of Ogun Phosphate rock was carried out with Four pellets of Ogun phosphorites labeled OG1, OG2, OG3 and OG4 randomly selected and subjected to X-ray fluorescence analysis. Major element analysis of the Ogun Phospahte Rock was undertaken on powdered samples mixed with pure lithium metaborate, and ammonium nitrate as the oxidizing agent fused to a glass disc in a furnace at 1000 ºC. Trace elements analysis was undertaken on a 32 mm diameter 10 g pressed powder pellet (Norish and Hutton 1969; Hutchison 1974) using Philips X'Unique II and PW 1404 spectrometers at the University of KwaZulu-Natal. The Loss on Ignition was calculated from a weight loss of a sample heated to 1000 °C (Hutchison 1974)

Statistical Analysis

The data collected were subjected to Analysis of variance (ANOVA) using the Statistical Analysis System (SAS) – General Linear Model (SAS, 2000).

RESULTS AND DISCUSSION

Results of the chemical analysis carried out on soil samples collected from the three experimental sites were shown in Table 1, pH value ranged from 5.8 in Ibadan to 6.6 in Ikenne. The organic carbon values varied from 0.96 g kg^{-1} (Abeokuta) to 1.23 g kg^{-1} (Ikenne). The total nitrogen content varied also in the same trend and the values were low in all the soils. The available P was highest in soils at Ibadan (54.36 mg kg^{-1}) and lowest in Ikenne (7.34 mg kg^{-1}). Exchangeable cations like calcium ranged from 2.77 cmol kg^{-1} at Abeokuta to 2.96 cmol kg^{-1} at Ibadan. Exchangeable Mg was highest (1.18cmol kg^{-1}) in lkenne and least (0.68 cmol kg^{-1}) in Abeokuta while K was highest Ibadan (0.77 cmol kg^{-1}) and lowest in Ikenne (0.17. cmol kg^{-1}). Exchangeable sodium varied from 0.05 cmol kg^{-1} (Abeokuta) to 0.10 cmol kg^{-1} in Ibadan. Micronutrients like iron was highest in Ibadan (138.9 kg ha^{-1}) and least in Abeokuta (95.9 kg ha^{-1}), while manganese was highest in Abeokuta (246.43 kg ha^{-1}) and least in Ikenne (202.88 kg ha^{-1}). Chemical analysis of legumes biomass is shown in Table 2. Higher values in N, P, Ca, Lignin and cellulose were obtained with mucuna tissue compared with cowpea. Organic matter content of raw OPR was 0.31%, Characterization studies of Ogun phosphate rock was carried out at school of Geological sciences, University of KwaZulu-Natal South Africa (Adesanwo *et al.*, 2010). Results of the X – ray fluorescence (table 3) showed wide variations in elemental composition among the different forms of Ogun phosphorites. The Al_2O_3, SiO_2, Fe_2O_3 and LOI values constitute over 90 % by weight of the rock material. LOI values which represent combination of moisture and CO_2 confirm the result from the laboratory. Radionuclides are in minute amount. (Adesanwo *et al.*, 2010).

Greenhouse Studies

There was significant increase in organic carbon as a result of Ogun phosphate rock addition ($p < 0.05$) in the greenhouse with soil samples from Ibadan but no significant effect was observed with samples from other two sites and on the field. But gradual increase was noticed, for instance an increase of 8.2%, 12.5% and 14.8% in organic carbon was recorded for OPR applied at 30, 60 and 90 $kgha^{-1}$ respectively over control pot for soil sample from Abeokuta without incorporation of legume. Pots treated with combination of mucuna and OPR at 30 kg ha^{-1} increased organic carbon by 8 % over pots receiving only mucuna with samples from Ikenne. Increases of 6.5 and 6% were recorded with soil samples from Ibadan and Abeokuta when 30 kg P /ha^{-1} of OPR was applied without legume over the control pot. Similarly, increases of 11 and 8.2 % were recorded for samples treated with mucuna and OPR at 30 kg ha^{-1}. Increase in percent organic carbon for sample treated with legume biomass over no legume biomass was an indication of contributory effect of legume incorporation on organic carbon thus confirming earlier work done (Tian *et al.,* 1992).

Field Experiment

Results from the two year field experiment conducted to evaluate the effect of phosphate rock addition with and without legume on soil organic carbon was positive though no significant effect of added OPR was recorded in all the three sites but gradual increase was observed (Figures 1, 2 and 3). For example, an increase of 30 % in organic carbon was observed with plots treated with mucuna biomass and phosphate rock at 90 kg P ha^{-1} at Ibadan (1.70%) over plots receiving only mucuna biomass (1.19%) on the field. Despite the fact that no fresh addition of OPR was made during the second field trial, gradual increase in OPR treated pots over the control was observed. More importantly, decrease in organic carbon content after the second field trial with legume biomass was a clear indication of the contributory effect of added OPR. Previous work done showed that organically managed soils can convert carbon dioxide from a greenhouse gas into a food-producing asset. Combined use of legume biomass and phosphate rock has advantages of increasing the carbon sink of soils apart from other beneficial use like improving the P status of slightly acidic to slightly alkaline soils. It also adds micro and macro nutrients to soils (Adesanwo *et al.*, 2010, 2011). It is imperative to explore potential of this natural resource which is cost effective and environmentally friendly.

CONCLUSION

Results from this project showed a positive effect of phosphate rock addition on soil organic carbon by increasing the carbon sink of soils. More research work is needed to ascertain long time benefit of Ogun phosphate rock in improving the soil carbon sink.

ACKNOWLEDGEMENTS

African Rice Center, IITA, Ibadan in collaboration with University of Hohenheim, Germany offered fellowship to carry out doctoral Research. The assistances given by Dr. O. A. Osiname (Retired) of African Rice Center, IITA Ibadan; and Prof. Norma Dunlevey (Retired) School of Geological Sciences, University of KwaZulu-natal, Durban, South-African are acknowledged.

Table 1: Chemical properties of soil samples taken at soil depth 0-20cm from the three experimental sites

Parameters	Ibadan (IITA)	Ikenne (IAR&T)	Abeokuta (UNAAB)
pH (H_2O) 1:1	5.8	6.6	6.2
C (g kg^{-1})	1.21	1.23	0.96
N (g kg^{-1})	0.11	0.11	0.08
P (mg kg^{-1})	54.36	7.34	10.18
Exchangeable cations (cmol kg^{-1})			
Ca	2.77	2.91	2.96
Mg	0.70	1.18	0.68
K	0.77	0.17	0.23
Na	0.10	0.06	0.05
Micronutrients (kg ha^{-1})			
Fe	138.9	98.8	95.9
Mn	236.44	202.88	246.43
Zn	2.39	1.08	1.83
Cu	1.41	1.65	1.35
Particle size (%)			
%Sand	74	68	80
%Clay	12	10	8
%Silt	14	22	12

Table 2: Chemical composition of legume biomass

Parameters (%)	Mucuna	Cowpea
N	3.45	2.58
P	0.21	0.08
Ca	0.4	0.3
Mg	0.35	0.28
K	0.87	2.56
Lignin	6.44	4.09
Cellulose	21.94	16.97

Table 3 Major and Minor Element in different forms of the Ogun Phosphate Rock

	OG1	OG2	OG3	OG4	OGMIX
SiO_2	2.21	24.67	6.77	26.98	23.32
Al_2O_3	1.55	5.07	7.47	6.84	10.44
Fe_2O_3	4.74	9.34	6.28	25.78	11.99
CaO	46.80	25.66	35.72	14.43	18.55
P_2O_5	31.28	19.73	30.20	11.12	17.61
TiO_2	0.07	0.23	0.22	0.36	0.39
MgO	0.39	0.37	0.41	0.30	0.59
MnO	0.16	0.11	0.17	0.09	0.14
Na_2O	0.53	0.30	0.19	0.10	0.18
K_2O	0.08	0.10	0.17	0.10	0.20
LOI	11.67	13.37	12.77	13.29	16.27
Total	99.48	98.95	100.37	99.39	99.68

†. The LOI represents the combined moisture and CO_2 loss.
Source: *Adesanwo et al., 2010.*

Table 4 Effects of treatments on soil organic carbon in the greenhouse at 9 weeks after planting using soil samples from the three sites

Treatments			**Org. C (gkg-1)**	
Legume	**P rates (kg ha-1)**	**Ibadan**	**Ikenne**	**Abeokuta**
No Legume	0	0.71	1.02	0.63
	30	0.76	0.83	0.67
	60	0.74	0.91	0.72
	90	0.77	0.89	0.74
	TSP	0.80	1.00	0.65
Mucuna	0	0.81	0.78	0.73
	30	0.91	0.85	0.72
	60	0.80	0.83	0.75
	90	0.79	0.88	0.73
	TSP	0.78	0.81	0.73
Cowpea	0	0.72	0.98	0.73
	30	0.89	0.86	0.81
	60	0.86	0.89	0.77
	90	0.86	1.00	0.81
	TSP	0.73	0.84	0.78
LSD ($p \leq 0.05$)	L	**	NS	**
	P	**	NS	NS
	L x P	**	*	NS
	R2	95	90	84

†*** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$ and NS = not significant.

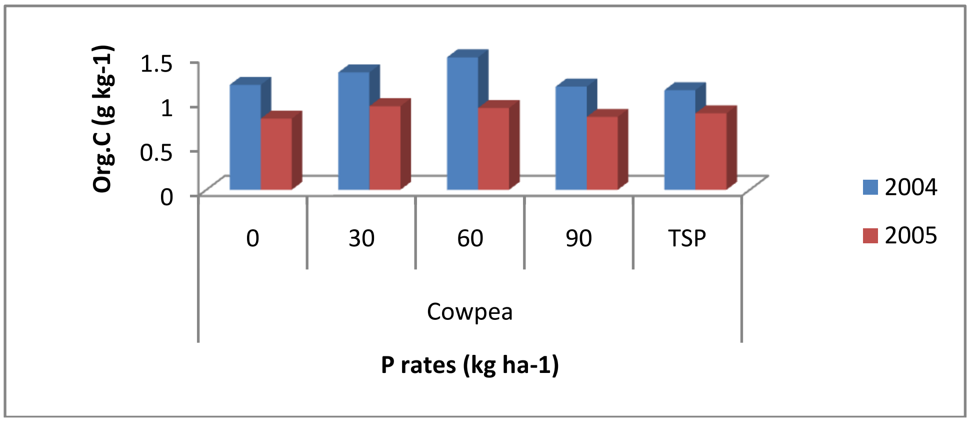

Figure 1: Rate of application of OPR (i) without legume (ii) with mucuna and (iii) with ccowpea on Soil Organic Carbon with samples from Ibadan

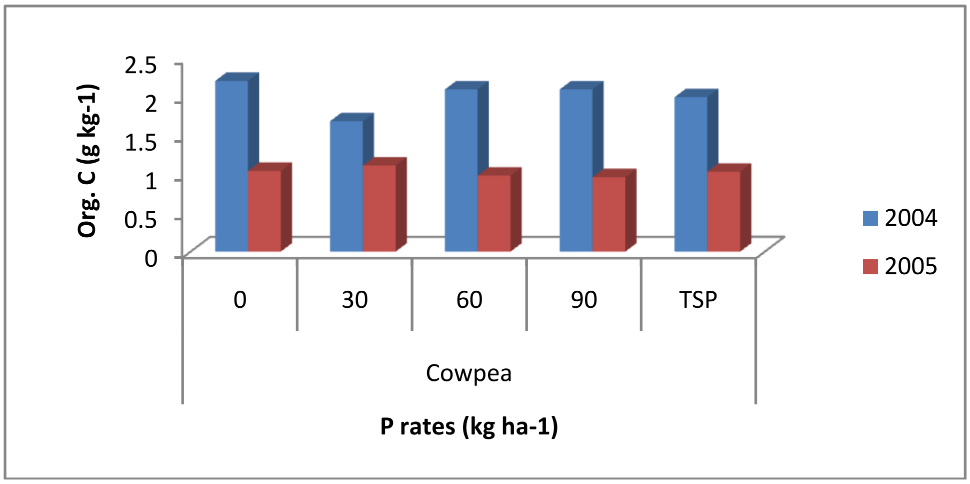

Figure 2: Rate of application of OPR (i) without legume (ii) with mucuna and (iii) with ccowpea on Soil Organic Carbon with samples from Ikenne

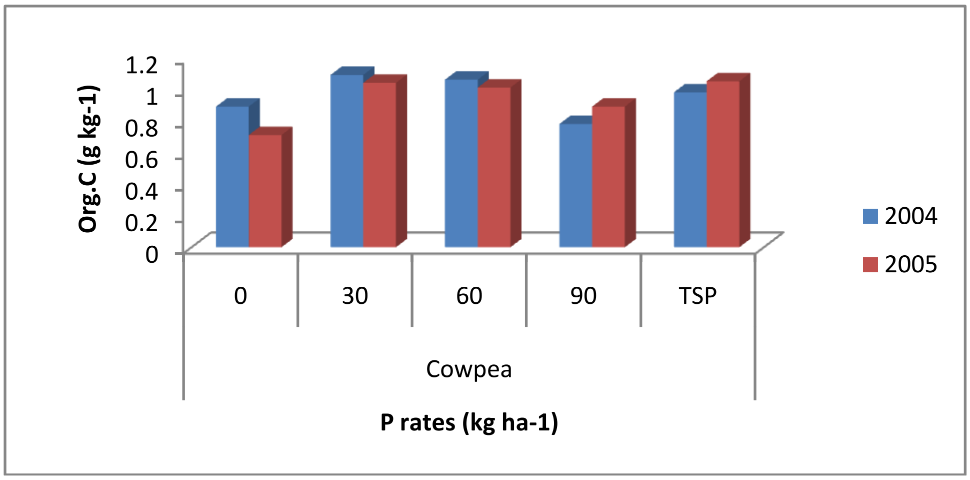

Figure 3: Rate of application of OPR (i) without legume (ii) with mucuna and (iii) with ccowpea on Soil Organic Carbon with samples from UNAAB

REFERENCES

Adesanwo, O.O., Adetunji, M .T., Dunlevey, J.N., Osiname O.A., Diatta, S., Adesanwo, J. K. (2010) Geochemistry and Mineralogy of Ogun Phosphate Rock, *African Journal of Environmental Science and Technology*, 4(10): 698 -708, Academic journals

Agboola, A. A. and Ogunkunle, **A. O.** (1993). Site characterization of Epemakinde, Ondo State, Nigeria. *Technical Report on Land Development for Sustainable Agriculture in Africa*. Bangkok, Thailand: IBSRAM/AFRICALAND Network. pp. 121–131.

Akande, M. O., E. A Aduayi, R.A. Sobulo and A. Olayinka, (1998). Efficiency of Rock phosphate as fertilizer source in South – western, Nigeria. *Journal of Plant Nutrition* 2 : 1339 – 1353.

Allan, Y. (2005) Priority One: Together we can beat global warming.

Bouyoucos, G.J. (1962) Hydrometer methods Improved for making particle size analysis of soils, *Soil Science Society of America Proceedings* : 26 : 464 – 465.

Bray, R.M. & Kurtz, L.T. (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Science*, 59: 39-45

FAO-UNESCO (1977). Soil Map of the World, Africa. Publ. FAO-UNESCO, Paris, 299 pp.

Hutchison CS (1974). *Laboratory handbook of Petrographic techniques*. New York: John Wiley.

Mclean, E.O. (1982). Soil pH and Lime Requirement. In: *Methods of Soil Analysis*, Part 2, A.L. (Ed.). ASA and SSSA, Madison, WI., ISBN: 0-8493-0022-3, pp: 192-224.

Mehra, P.O and Jacksson, M.L (1960) Iron – oxide removed from soils and clays by a dithionite-citrate system with sodium bicarbonate buffer. *Clays and Clay Minerals*, 7, 317

Pimentel, D., Hepperly, P., Hanson, J., Douds, D. and Seidel, R. (2005). "Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems". *Bioscience* **55** (7): 573–82

SAS Institute Incorporation. 2000. *SAS/STATH User's Guide:* Version 8, vols. 1–3.Cary, N.C.: SAS

Soil Survey Staff (1975). *Soil taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Survey*. USDA Handbook 436. Washington, DC: U. S. Government Printing Office.

Tian , G., B. T. Kang & L. Brussaard (1992). Effects of chemical composition on N, Ca, and Mg release during incubation of leaves from selected agroforestry. *Biogeochemistry* 16:103-119, 1992

Walkley, A. and Black, I . A. (1934). An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Science* 37 : 29 – 38.