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The Effect of Organic Waste Addition on Biochemical Factors and Availability of Phosphorus in Desert Soils

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Abstract

Phosphorus is an essential nutrient. In spite of its wide distribution in nature, P is a limited resource and it is deficient in most soils. This study is aimed to evaluate availability of phosphorus in desert soil with a sandy texture, treated with organic waste (dung of sheep) at rates of different additions (amount applied at 30, 60, 90 & 120 tons. ha-1) over 12 weeks, to find out the effect of pH on soil rates mineralization at various applications. Used soil samples were collected from the surface layer (0-30cm) of arable soils. Available phosphorus determinate as stated in Olsen. It was appreciated colorometrically according to Murphy and Riley. Soil pH measure of extracts 1:1 (soil/solution ratio) according to Jackson. The results showed that the soil pH changed in range 7.5 to 7.8 which increased the phosphorus concentration in the soil. So there were significant changes in biochemical soil factors due to bacterial groups and phosphatase activities which were responsible for mineralization. The results show that available phosphorus improved at rate of 254.47-301.01ppm in fourth week for all applications, which refers to increase of biological activity of soils by adding organic waste and led to a significant increase in available phosphorus concentration.

Keywords: Effect, Phosphorus, Desert soils, Organic waste, Mineralization, pH, Biochemical factors, Microbial groups.

1. Introduction

Phosphorus is an essential nutrient. In spite of its wide distribution in nature, P is a limited resource (Adnan, A. et al, 2003, Shimamura, K. et al, 2003) and it is deficient in most soils (Vassilev, N. et al, 2001). Soil P exists in various chemical forms, including inorganic P (Pi) and organic P (Po), which differ widely in their behavior and fate in soils(Turner, L. et al, 2003a, Turner, L. et al, 2003b, Hansen, J. C. et al, 2004), specifically in relation to bioavailability, as various forms can undergo cycling at different rates, being retained in soils or made available to plants (Chen, R. et al, 2003,. De Brouwere, K, 2003, Nwoke, O. C., 2003).

Organic phosphorus in soils is present as phosphorus compounds in organic or inorganic forms accounts for 20 to 80% of total phosphorus (Tate, k. R. 1985). A source of organic phosphorus in soil became organic matter derived from roots, plant residues and added organic fertilizer, where the validity of organic compounds to plant nutrition depend on many factors; the most important is soil pH. Plants in order to take advantage from organic phosphorus must first be converted to mineralizable phosphorus by a process mineralization as a result of different micro-organisms activity.

The process of phosphorus mineralization is similar to nitrogen, and as a general, phosphorus mineralization occur more rapidly under the appropriate conditions as ammonification, where is studies had indicated (Criquet, S.V. and Braud, A., 2008) that there an important relation between nitrogen and phosphorus mineralization. However, several factors effecting organic phosphorus mineralization such as carbon to phosphorus ratio (C/P ratio) where the addition of organic matter to soil does not mean that it lead to the organic phosphorus mineralization, but it may lead to immobilization as a direct effect on process of mineralization (Criquet, S.V. and Braud, A., 2008), Thereby, C/P ratio identify the prevailing direction after organic matter addition, if the ratio was 1:200 or less it be the mineralization, while the ratio 1:300 or more means available phosphorus lost as a result of immobilization. Therefore, all factors affecting the activity of soil bacteria, such as temperature, moisture, aeration, pH and density of vegetation have a significant effect on process of mineralization (Magid, J. et al, 2004, Thomsen, I.K. et al, 2003, Müller, T. et al, 2005, Sierra, J., 1997, Stottlemyer, R. et al, 2001). In most arable land useful bacteria and fungi lives that break down and dissolve phosphorus, where they play a very important role in decomposition and dissolve phosphorus, and convert it into a soluble form that can be absorbed, leading to increase of phosphorus concentration dissolved in soil. However, the presence of these microorganisms increase the soil fertility and raise the productivity, where the most important types of them are Pseudomonas Bacilus, Enterobacter, and the most important fungi are Penicillium, Rhizopus, Aspergillius, where norepinephrine a large quantities of organic acids with low molecular weight that lead to the increase of phosphorus concentration dissolved in soil solution, and where these organic acids remove phosphorus from calcium, iron and aluminum phosphatase a result of replacement reactions and then convert phosphorus into a soluble form ($H_2PO_3^-$, HPO_4^{-2}), which can be absorbed by the plant. It also releases in acid and alkaline phosphatases enzymes that lead to increase in solubility of phosphorus and convert it into a form that can be absorbed by plants. Moreover, there are some dissolving phosphorus organisms that do not release an organic acid, but dissolve phosphorus through the production of protons associated with the process of respiration, leading to soluble phosphorus, which is one of the major elements for the growth and nutrition of plants in all stages and is the second element after nitrogen.

The problem of P deficiency can potentially be solved by the progressive return of organic materials to soil; however, the quantity, quality and management of this practice are fundamental factors that affect P availability from residues (Kwabiah, B. et al, 2003a). Identification of P in waste (both its organic and inorganic forms) is a fundamental prerequisite to understanding nutrient dynamics in soil-waste systems and the mechanisms responsible for the release of potentially bioavailable forms of P over time. For effective P recovery from organic residues incorporated in soil, it is fundamental to identify the P distribution patterns in residues and subsequently in soil, which will help determine the optimal conditions for P release to plants. This review presents the critical factors that influence the bioavailability of phosphorus from organic waste in soil.

For P from organic compounds to be available, it needs to be hydrolyzed and mineralized by the microbial biomass, which is a fundamental process for the release of orthophosphate ions to plants (Haygarth, P. M. Jarvis, S. C., 1997, Hayes, J. E. et al, 2000, Borie, R., 2003, Oehl, E.et al, 2004) and the maintenance of the P cycle in ecosystems. Through a mineralization process, Po compounds represent an important P source for plants and microorganisms (Makarov, M. I. et al, 2005), in soil with low levels of bioavailable P and in unfertilized cropping systems (Parfitt, R. L. et al, 2005). However, the effective availability of P compounds applied to soil from wastes depends firstly on the form of P added, and later on the external factors that contribute to increased or decreased availability over time.

The incorporation of organic residues can improve soil conditions making an increase in P availability possible. The improvement in P availability following residue amendment depends on residue characteristics which reduce P adsorption strength in soils (Haynes, R. J. and Mokolobate, M.S., 2001) and the bioavailability of P compounds incorporated into the soil.

Organic waste incorporation, specifically compost and manure, increases pH values in mixed waste-soil. This pH increase can be associated with specific adsorption of organic molecules by ligand exchange with the release of OH- ions during organic matter mineralization, proton consumption by functional groups associated with organic materials, proton consumption during decarboxylation of organic acid anions and the release of OH- during reduction reactions (Speir, T. W. et al, 2004).

It has been proven that organic waste incorporated into soil has an influence on the composition and enhancement of microbial biomass, and therefore produces changes in enzymatic activity. (Speir, T. W. et al, 2004, Oehl, A. et al, 2001) found that organically cultivated soil revealed higher microbial biomass than conventionally cultivated soil and non-fertilized soil, indicating that microbial P in organically cultivated soil (17.6 – 16.5 mg kg^{-1}) was higher than conventionally cultivated and non-fertilized soil (9.0– 8.0 mg kg^{-1}). The organic field had a higher microbial biomass content and activity than soils of a conventionally cropped field. (Marinari, S. et al, 2006) used chemical and microbiological properties as indicators of soil quality after 7 years of organic and conventional management methods.

Because of the importance of phosphorus, this study is aimed to identify the impact of compost application on phosphorus availability and its relationship with phosphatase bacteria.

2. Materials and Methods

2.1 Study Area

For the purpose of the study, soil samples were collected from the surface layer (0-30cm) of arable soils in the area of Zarqa region (southern Jordan). Used pots units test included transactions to add (manure sheep) at rates (0, 30, 60, 90 & 120 ton. ha^{-1}) which were incubated for several periods: one week, two weeks, 4 weeks, 6 weeks, 8 weeks, 10 weeks and 12 weeks, between March and July, where the temperature ranged from 32-38C^{O}.

2.2 Methods of Soil Analysis

Electrical Conductivity (EC) Estimated in soil extracts (1:1) by using Conductivity meter as $dS.m^{-1}$ at 25 C° according to (Richards, L.A., 1954.). Soil pH measure of extracts (1:1, soil: solution) using pH meter, according to (Jackson, M.L., 1973). Percentage of moisture was estimated gravimetric according to (Aledumi, M. F., 2000) by drying 50 g soil at a temperature 105 C° for 24 hours. Porosity was calculated using the equation described by (Darbi, T., 1995), were Bulk density calculated in a cylinder, according to (Sing, R. A., 1980). Particle Density (ρ_s) determinate as reported by (Pycno meter), according to (Baruah, T.C., Barthokur, H. P., 1997). Soil texture identified using the pipette method mentioned by (Kilmer, V. J. and Alexander, L. T., 1949) and as reported in (Sing, R. A., 1980). For mechanical analysis, soil samples air-dried and sieved to 2 mm before separation. Briefly, 50 g of soil dispersed ultrasonically (300W for 15 min) in 150 ml of water with a probe-type disintegrator. Clay-sized (2 mm) and silt-sized (2–20 mm) fractions were obtained by repeated gravitational sedimentation in water, the sand (20–2000 mm) being recovered as the sediment left after isolation of clay and silt. Clay particles in decanted suspensions flocculated by addition of $CaCl_2$ and concentrated by centrifugation. Available phosphorus determinate as stated in (Olsen, S.R. et al, 1982), followed by colorimetric analysis on a technicon autoanalyzer according to (Murphy, J. and Riley, J.P., 1962). Briefly, this method estimates the relative bioavailability of orthophosphate (PO_4-P) using 0.5N $NaHCO_3$ adjusted to pH 8.50 for soils mildly acidic to alkaline pH and is based on the method developed by (Olsen, S.R. et al, 1982). In the process of extraction, CO_2 from bicarbonate is driven off, pH increases and bicarbonate converts to carbonate. Thus there is lower calcium activity as calcium carbonate is formed increasing the quantity of phosphates in solution. Phosphorus content is determined spectrophotometrically at 882 nm at an acidity of 0.24 MH_2SO_4 by reacting with ammonium molybdate using ascorbic acid as a reductant in the presence of antimony using automated techniques.

3. Results and Discussion

The results mentioned in Table (1) show that soil pH is neutral to the alkaline (7.2-7.8). It is well known (Speir, T. W. et al, 2004, Oehl, A. et al, 2001) that phosphorus and many micronutrients affected by high pH which may cause volatility of nitrogen or phosphorus fixation and transforms the iron and manganese to oxides by precipitation, leading to decrease availability for plants. The results showed that Electrical Conductivity was 3.59, due to the high percentage of salt which is considered widespread in arid and semi-arid regions, represented by Wadi-Alshati. The porosity was within a normal range, which contributes to the good aeration of soil and accessibility movement of water through it (Rajab, M., 2008). The moisture content was 7.5% which is close to what was (Rajab, M., 2008) found 5.27 - 21.06% in surface layer of cultivated soils for this region, because of the excessive use of irrigation, which effects the rates of soil wet and an indication of soil ability to retain water, while the porosity effects the movement of water, nutrients, aeration and therefore microbial activity in soil.

Table 1 Physical properties of studied soil

Bulk density	***1.69*** $g.cm^3$			
Particle Density	***2.47*** $g.cm^3$			
PORISTY	***% 0.32***			
ELECTRICAL CONDUCTIVITY AT **25** C°	***3.59*** ms			
MOSTURE	***% 7.5***			
SOIL TEXTURE	SILT 6.8%	SAND 83.67		CLAY 9.49%
pH	***0*** $t.ha^{-1}$	***30*** $t.ha^{-1}$	***60*** $t.ha^{-1}$	***90*** $t.ha^{-1}$
	7.2	***7.5***	***7.5***	***7.8***

The results indicate that incubation periods affect phosphorus availability in soil, where it decreased after two weeks (second period) of incubation and reached (13.26-31.22%), but it was noted significant rise in available phosphorus concentration during third period of incubation (4 weeks), also it was observed that there was decrease on phosphorus concentration when time of incubation increased, where it was more in fourth period of incubation (6 weeks) compared to the decrease occurred in the second period (two weeks), which is consistent with what found (Alrehely, K. M., 2007) where greater portion of added phosphorus undergo to adsorption. The results indicate that the amount of added fertilizer had an impact on available phosphorus in soil, which is observed directly, where the values of available phosphorus was 74.13-78.06-87.95-85.91-92.67 ppm respectively for additions (0, 30, 60, 90 and 120 tons/ha^{-1}), this means that the phosphorus becomes more available after additions directly and there is a continuous increase in available phosphorus with increase of organic additions, and in general, we find that, in spite of loss a part of added phosphorus through the fixation, but high additions always raise the level of available phosphorus in soil.

As shown in Table (2) and figure(1), the results indicate that organic manure added to soil gradually mineralize and decreased to 13.26% after two weeks of incubation in untreated soil, and 24.94% at 60 tons/ha^{-1}, an approach to treatment of 60 tons/ha-1 where was 23.41%. The lowest level of mineralization was at treatment 90 tons/ha^{-1} and reached 2.95% which is very low and indicate the weakness of biological activity of soil, while the highest rate of mineralization was at treatment of 120 tons/ha^{-1} and reached 31.22%, which means occurrence of vital activity microbial in soil. Phosphorus increase due to the low proportion of carbon to phosphorus in the soil and lack of energy source for microorganisms consuming phosphorus, which is the main source of life cycle, as well as, the high rates indicates a decomposition of microorganism's bodies containing phosphorus. More critical periods of added phosphorus observed in sixth week, where a significant decrease in phosphorus concentration in treated soil declined which occur when the incubation period was increased.

The results show that the values of phosphorus in soil and their relationship to the period of incubation and rate of fertilizer addition may vary according to the rate of additions, were phosphorus dissolving bacteria plays an important role in improving the properties of soil and increase soil fertility and the efficiency of phosphate fertilizer by dissolving non-absorbable phosphorus into a form that can be absorbed and dissolved in soil. In 1 cm^3 of fertile soil present 6-10 million units, while in 1 cm^3 of poor soil number of bacteria does not exceed 450 thousand units, therefore, soil treatment with manure increases enumerate bacteria and its growth as a result of abundance of required nutrients. It was evident when measuring the number of bacteria in 1 gram of prepared soil were number ranging 50-120 million units. Criquet, S.V. and Braud, A., 2008, pointed out that addition of organic matter led to an improvement in biochemical soil factors ,changes in activities of phosphatase and increased microbial mass, (Lima, J.A. et el, 1996) indicated that use of Organic fertilizer lead to improve rates of plant productivity because they contain phospholipids compounds and increased microbial activity in soil. As mentioned by (Petit, J. et al, 2004) that about 70% of phosphorus present in organic form, while by mineralization microbes convert organic phosphorus to orthophosphate by means of enzymes secreted by microorganisms able to organic phosphorus decomposition by hydrolyses to phosphate by groups of phosphatases which affected Soil properties. The most important types of phosphorus dissolving bacteria is genus of Pseudomonas Bacilus and Enterobacter, which produces organic acids with low molecular weight, leading to increased concentration of phosphorus facilitator, were we Isolate 95 different types of beneficial bacteria-dissolving phosphorus, which used organic matter as a source of energy, which is consistent with what pointed by (Radwan, T. D., 2006) that found microbial Vaccination in soil encouraged available phosphorus and some micronutrients in the soil (iron, manganese, Zinc, copper).

Table 2 Results of phosphorus mineralization in manure amended soils

Time/weeks	Applications t.ha^{-1}				
	0	***30***	***60***	***90***	***120***
0	74.13	78.06	87.95	85.91	92.67
2	64.3	58.59	67.36	83.37	63.74
4	254.47	300.04	259.56	269.98	301
6	21.03	35.05	39.03	39.41	51.34
8	37.64	50.19	41.01	48.04	55.43
10	62.34	62.87	65.37	67.21	71
12	47.56	48.46	49.66	54.16	55.66

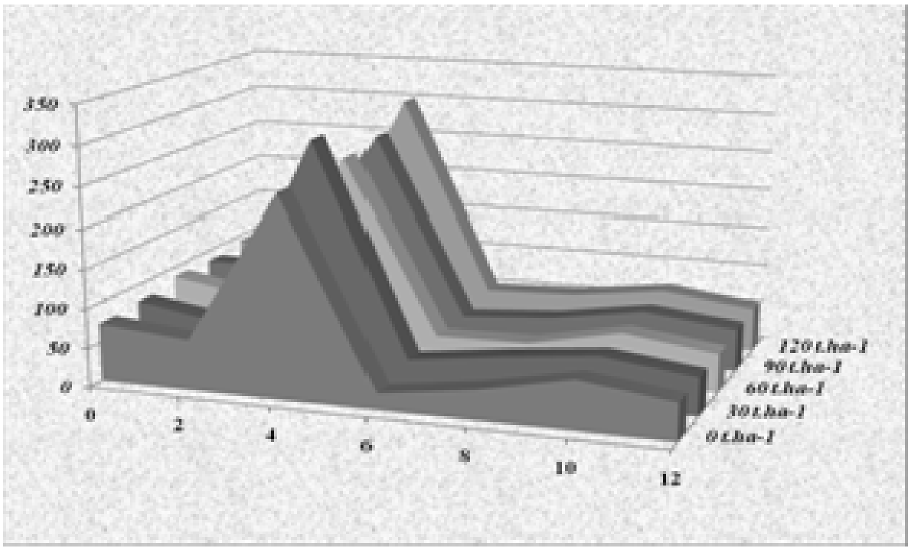

Figure1. Rates of mineralization at different applications in manure amended soil

4. Conclusions

Based on obtained results it can be concluded, that adding dung of sheep led to increase phosphorus availability in soil by increasing rates of applications, while increasing periods of incubation lead to a reduction in phosphorus availability and reached to maximum within 4th week from incubation. Mineralization process occurs at different rates and affected by microbial groups that led to phosphorus mineralization. The study recommends the additions dung of sheep with appropriate proprieties and activity of microbial groups in soil which helps phosphorus to be available at natural organic source. The use of waste helps to eliminate the negative environmental impacts and increase the organic matter in desert soils.

References

Adnan., D. S. Mavinic, F. A.. Koch, Pilot-scale study of phosphorus recovery through struvite crystallization - examining the process feasibility. Journal Environ. Eng. Sci. 2, 2003, pp. 315–324.

Aledumi, M. F., Fundamentals of Soil Science and Applications", published by Dar al-Bashir. Foundation of the message, 2000.

Alrehely, K. M., Effect of organic fertilizers on phosphorus availability in calcareous soils, Department of Soil Science, Faculty of Food and Agricultural Sciences - King Saud University, 2007.

Baruah, T.C., Barthokur, H. P., Atext Book of Soil Analysis, Vikas publishing House PVT–LTD First published, printed pashupati printes, Delhi-Indi, 1997.

Borie, R. Rubio, Total and organic phosphorus in Chilean volcanic soils. Gayana Bot., 60(1), 2003, pp. 69-78.

Chen, R., Sinaj, S., Condron. L. M., Frossard, E., Sherlock, R. R., Davis, M. R., Characterization of phosphorus availability in selected New Zealand grassland soils. Nutr. Cycl. Agroecosys, 65, 2003, pp. 89-100.

Criquet, S. V., Braud, A., Effects of organic and mineral amendments on available P and phosphatase activities in a degraded Mediterranean soil, under short-term incubation experiment ,Soil & Tillage Research 98 2008, pp.164–174.

Darbi, T., Fundamentals of Soil Physics, King Saud University, Saudi Arabia, 1995.

De Brouwere, K., Thijs, A., Hens, M., Merckx, R., Forms and bioavailability of soil phosphorus in temperate forests in southern Chile and Flanders. Gayana Bot, 60 (1), 2003, pp. 17-23.

Hansen, J. C., Menun, B. J.,. Strawn, D. G., Phosphorus speciation in manure amended alkaline soils. J. Environ. Qual., 33, 2004, pp. 1521- 1527.

Hayes, J. E., Richardson, A. E., Simpson, R. J., Components of organic phosphorus in soil extracts that are hydrolysed by phytase and acid phosphatase. Biol. Fertil. Soils,32, 2000, pp. 279-286.

Haygarth, P. M., Jarvis, S. C., Soil derived phosphorus in surface runoff from grazed grassland lysimeters. Wat. Res. 31(1), 1997, pp. 140-148.

Haynes, R. J., Mokolobate, M.S., 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. Agroecosys, 59, 2001, pp. 47-63.

Jackson, M.L., Soil chemical analysis, Print. Hall., India, 1973.

Kilmer, V. J., Alexander, L. T., Methods of making mechanical analysis of soils. Soil Sci., 68, 1949, pp. 15-24.

Kwabiah, B.,. Stoskopf, N. C, Palm, C. A., Voroney, R. P., Rao, M. R., Gacheru, E., Phosphorus availability and maize response to organic and inorganic fertilizer inputs in a short term study in western Kenya. Agric. Ecosys. Environ. 95, 2003a, pp. 49-59.

Lima, J.A., Nahas, E., Gomes, A.C., Microbial populations and activities in sewage sludge and phosphate fertilizer-amended soil. Appl. Soil Ecol. 4, 1996, pp.75–82.

Magid, J., Luxhfi, J., Lyshede, O.B., Decomposition of plant residues at low temperatures separates turnover of nitrogen and energy rich tissue components in time, Plant Soil 258, 2004, pp. 351-365.

Makarov, M. I., Haumaier, L., Zech, W., Marfenina, O. E., Lysak, L. V., Can 31P NMR spectroscopy be used to indicate the origins of soil organic phosphates? Soil Biol. Biochem., 37, 2005, pp. 15-25.

Marinari, S., Mancinelli, R., Campiglia, E., Grego, S., Chemical and biological indicators of soil quality in organic and conventional farming systems in Central Italy. Ecological Indicators 6, 2006, pp. 701-711.

Mokolobate, M. S., Haynes, R. J., Increases in pH and soluble salts influence the effect that additions of organic residues have on concentrations of exchangeable and soil solution aluminium, European Journal of Soil Science, 53(3), 2002, pp. 481–489,

Müller, T., Fragstein, V. P., Vegetabile Düngemitte l: I. N-Umsatz in Bode be Incubations experiment and in Feldversuchen. In Heß, J., Rahmann, G., Kassel (Germany), 1st – 4th, 2005, pp. 205-208.

Murphy, J., Riley, J.P., A modified single solution method for determination of phosphate in natural water. Anal. Chemistry. Acta 27, 1982, pp. 31-36, Method of soil analysis part 2, Phosphorus, 1962, pp.402-430.

Nwoke, O. C., Vanlauwe, B., Diels, J., Sanginga, N., Osonubi, O., Merckx, R., Assessment of labile phosphorus fractions and adsorption characteristics in relation to soil properties of West African savanna soils. Agric. Ecosys. Environ., 100, 2003, pp. 285-294.

Oehl, A. Oberson, M. Probst, A. Fliessbach, H.R. Roth, E. Frossard Kinetics of microbial phosphorus uptake in cultivated soils. Biol Fert Soils 34, 2001, pp. 31-41

Oehl, E. Frossard, A. Fliessbach, D. Dubois, A. Oberson, Basal organic phosphorus mineralization in soils under different farming systems. Soil Biol. Biochem., 36, 2004, pp. 667-675.

Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean, L.A., Estimation of available phosphorus in soils by extraction with sodium bicarbonate, USDA Circular No 939, 1982.

Parfitt, R. L., Yeates, G. W., Ross, D. J., Mackay, A. D., Budding, P. J., Relationships between soil biota, nitrogen and phosphorus availability, and pasture growth under organic and conventional management. Appl. Soil Ecol., 28, 2005, pp. 1-13.

Petit, J., Criquet, S., Ferre, E., Farnet, A.M., Annual dynamics of phosphatase activities in an evergreen oak litter: influence of biotic and abiotic factors. Soil Biol. Biochem. 36, 2004, pp.1111–1118.

Radwan, T. D., The impact of microbiological activity on phosphorus availability in soil uptakes by bean plants in some developing modern land in Egypt, Institute of Soil, Water and Environment research, International journal for agricultural & biology, 2006, pp. 222-225.

Rajab, M., Determination of aviability of phosphorous in disert soil, Department of Environmental Science, Faculty of Engineering and Technology, Sebha University, 2008.

Richards, L.A., Diagnosis and improvement of saline and alkali soils, USDA Handbook 60, U.S. Government Printing Office, Washington, D. C., 1954.

Shimamura, K., Tanka, T., Miura, Y., Ishikawa, H., Development of a high-efficiency phosphorus recovery method using a fluidized-bed crystallized phosphorus removal system. Wat. Sci. Techol, 48 (1), 2003, pp. 163-170.

Sierra, J., Temperature and soil moisture dependence of N mineralization in intact soil cores, Soil Biol. Biochem.

29, 1997, pp. 1557-1563.

Sing, R. A., Soil Physical analysis, Kalyani Publishers, New Delhi, India, 1980.

Speir, T. W., Horswell, J., Van Schaik, A. P., Mclaren, R. G., Fietje, G.., Composted biosolids enhance fertility of a sandy loam soil under dairy pasture. Biol. Fertil. Soil, 40, 2004, pp. 349-358.

Stottlemyer, R., Rhoades, C., Steltzer, H., Soil Temperature, Moisture, and Carbon and Nitrogen Mineralization at a Taiga-Tundra Ecotone, Noatak National Preserve, Northwestern Alaska, U.S. Geological Survey, 2001, p. 1678.

Tate, k.R., Soil phosphorus. 1985. P. 329-377. In D. Vaughan and R.E. Malcolm (ed.) Soil organic matter and biological activity. M. Nilhof/Dr. W. Junk Publ., Dordrecht, the Netherlands.

Thomsen, I.K., Schjfnning, P., Christensen B.T., Mineralization of 15N-labelled sheep manure in soils of different texture and water contents, Biol. Fertil. Soils 37, 2003, pp. 295-301.

Turner, L., Mahieu, N., Condron, L. M., Phosphorus-31 nuclear magnetic resonance spectral assignments of phosphorus compounds in soil NaOHEDTA extracts. Soil Sci. Soc. Am. J. 67, 2003a, pp. 497-510.

Turner, L., Mahieu, N., Condron, L. M., The phosphorus composition of temperate pasture soils determined by NaOHEDTA extraction and solution 31P NMR spectroscopy. Organic Geochem. 34, 2003b, pp. 1199-1210.

Vassilev, N., Vassileva, M., Fenice, M., Federici, F., Immobilized cell technology applied in solubilization of insoluble inorganic (rock) phosphates and P plant acquisition. Biores. Technol., 79, 2001, pp. 263-271.

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