

HUMIFICATION OF ORGANIC MATTER IN SOIL AFFECTING AVAILABILITY
OF PHOSPHORUS FROM ITS INSOLUBLE MINERAL COMPOUNDS

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تأثير تحلل المادة العضوية في التربة على تيسير الفوسفور من مركباته الغير نائية

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ملخص البحث
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تم دراسة انطلاق الفوسفور الميسر من مركباته الغير نائية مثل خبث المعادن وصخر الفوسفات أثناء تحلل تبن البرسيم في أرض طينية رسوبية (pH 7.6) عند 60% من قدرة الأرض على حفظ الماء، والتحصين على درجة حرارة (20 ± 2^oم) لمدة 180 يوم.

اتضح من النتائج أن اضافة مركبات الفوسفور الغير نائية أدى الى ارتفاع محتوى عينات التربة من الكربون المتبطل بالمقارنة بالعينات التي لم يضاف اليها 0. كما وجد أن حامض الهيوميك يسود على حامض الفلنيك في جميع المعاملات 0 وكانت النسبة بين حامض الهيوميك الى حامض الفلنيك أكبر من واحد 0 كما وجد أن اضافة مركبات الفوسفور الغير نائية وتبن البرسيم أدى الى انخفاض نسبة حامض الهيوميك الى حامض الفلنيك وكان تأثير خبث المعادن على خفض هذه النسبة أكبر من صخر الفوسفات 0.

كما أوضحت النتائج زيادة كل من الفوسفور الصالح والفوسفور المرتبط باستخلاص المادة النباليه مع اضافة كل من تبن البرسيم ومركبات الفوسفور الغير نائية 0 وكذلك غرق خبث المعادن على صخر الفوسفات في زيادة صورتي الفوسفور المذكورتين 0

ABSTRACT

Release of available P from insoluble phosphate compounds, i.e. basic slag and rock phosphate, during humification of clover hay in a clay alluvial soil (pH 7.9) was studied at moisture level of 60% WHC and mesophilic incubation ($20\pm 2^\circ\text{C}$) along 180 days.

Content of total humified carbon in soil treated with insoluble phosphate compounds was higher than that in P-untreated soil. Humic acid predominated over fulvic acid in all soil treatments. Ratio of HA/FA was ever more than one, and it was decreased with the application of each of organic material and inorganic P compounds. Basic slag diminished the HA/FA ratio more than did the rock phosphate.

Humified and available P contents were augmented with the addition of each of organic material and insoluble phosphate compounds. Basic slag surpassed the rock phosphate in increasing both forms of phosphorus.

INTRODUCTION

Organic matter plays an important role in improving the physical, chemical, and biological properties of soils. It substantially contributes to the fertility of soil by providing plant nutrients via its decomposition. It also renders plant nutrients available from sources other than itself, e.g. soil minerals. Dalton et al. (1952), Datta and Nagar (1968), and Sinha (1972) suggested that soil organic matter or organic materials can make P available from the insoluble forms, namely, calcium phosphate, ferric phosphate, and aluminum phosphate. They explained the mechanism involved is such transformation as follows: During the decomposition of organic matter in soils, organic acids are produced, which may either influence the pH and consequently make P available from calcium phosphate, or they may form complexes or chelates with the cations and thus releasing the phosphate. It has also been reported that humus forms chelate with polyvalent cations, and it is likely that it may render P available in this manner from inorganic phosphorus compounds.

Datta and Goswami (1962), studying the decomposition of ^{14}C - and ^{32}P -labelled organic materials in soil in relation to the availability and uptake of nutrients by wheat plants in pot culture experiment, found that organic matter increased each of available P, plant uptake of P, and crop yield.

The influence of organic matter application on phosphate availability in soils may involve the composite effect of several processes occurring at various stages of decomposition and humification of added organic material (Sinha, 1972).

The aim of this investigation is to study the changes in availability of P from its insoluble mineral compounds (basic slag and rock phosphate) during humification course of organic material in an arid alluvial soil.

MATERIALS AND METHODS

Surface soil sample (0-30 cm) of Nile alluvium (Torrifluvents) was collected from the Experimental Farm, Faculty of Agriculture, Shebin El-Kom, Egypt. The sample was air-dried, ground to pass through a 2-mm sieve, and entirely mixed. Pertinent analytical data of the examined soil are presented in Table 1 (a&b). Methods of analysis were according to Jackson (1958).

Basic slag (by-product of iron industry) and rock phosphate (carbonate apatite), serving as insoluble phosphatic compounds, were finely crushed. Elemental analysis of these compounds was run after AOAC (1980); data are shown in Table (2). Pulverized clover hay (C 49.4%, N 0.84%, and P 0.12%) was employed as an organic supplement.

A number of polypropylene containers (7-cm wide, 5-cm high) was assigned to this study. In each container, 100 g of soil crumbs

Table 1. Analytical data of the alluvial soil under consideration.

a) Physical properties:

Organic matter %	Particle size distribution %			Textural grade
	CaCO ₃ %	Sand	Silt	
2.15	2.80	27.02	27.02	Clay

b) Chemical properties:

pH	E.C. **	C.E.C. meq/100 g	Total N %	Soluble ions (meq/100 g) **							
				Cations		Anions					
(1:2.5) *	mmho/cm	meq/100 g	P %	Ca ++	Mg ++	Na +	K +	Cl -	HCO ₃ -	CO ₃ =	SO ₄ =
7.90	0.44	28.60	0.10	0.80	0.45	1.12	0.33	0.88	0.95	-	0.95

* Soil: water suspension.
 ** In soil paste extract.

Table 2. Chemical composition of insoluble mineral phosphatic compounds used.

Phosphatic compound	P ₂ O ₅ %	CaO %	MgO %	Al ₂ O ₃ %	Fe ₂ O ₃ %
Basic slag	15.21	42.52	1.82	0.11	8.86
Rock phosphate	31.51	40.10	1.54	6.52	2.51

were packed. The soil containers were splitted into two groups for the following treatments:

- a. No organic material added.
- b. Organic material added.

Each group was further divided into three sets to satisfy the following subtreatments:

1. No P applied.
2. Basic slag.
3. Rock phosphate.

The organic material was added at a rate of 3% and the phosphate sources at 0.2% P. To each container of all sets, an activating mixture (0.05 mg potassium sulphate + 0.01 mg urea) was applied. These supplements were thoroughly mixed with the soil crumbs. 10 ml of fresh fertile soil-water suspension (1:5) were introduced to each container to serve as inoculum. Moisture content of soil was brought to 60% of the water-holding capacity with deionised water. All treatments were run in duplicates. Soil containers were left uncovered and incubated at the ambient room temperature ($20 \pm 2^\circ\text{C}$). Periodical sampling was conducted, along 180-day experimental duration, for C and P determinations. Moisture losses were compensated every three days with deionized water.

Soil samples were taken at certain incubation intervals dried at 70°C , then again ground and sifted. The non-humified materials were electrostatically removed, using rubbed plastic plate, according to Turin methods (Alexandrova and Naidenova, 1976).

The dried soil samples were then subjected to the following technique: 50 g of soil sample were placed in a 1000-ml polyethylene bottle, and 250 ml of freshly prepared 0.5 N NaOH were then added as

extractant, and 2.5-ml of concentrated Sn Cl_2 were added (Choudhri and Stevenson, 1957). The mixture was shaken by end-over-end shaker for one hour, then left to stand overnight (16-18 h) at room temperature. The suspension was hand-shaken vigorously and 5 g of Na_2SO_4 were added as coagulating agent for polyvalent cations. The mixture was centrifuged for 15 min. at 3000 rpm and the supernatant was transferred to a 250-ml volumetric flask, whereas the soil residue was discarded (Khalifa, 1979).

Contents of total organic carbon and humic substances-carbon in the mentioned supernatant were determined by means of Walkely and Black method (Jackson, 1958) taking in to consideration the recommendation of Kononova (1966).

For the estimation of total P of the humifying matter extracted from soil, 25 ml of the supernatant were pipetted into 100 ml-Erlenmyer flask which was then held on a boiling-water bath for complete evaporation. 5 ml H_2SO_4 conc. + 1 ml HClO_4 conc. were added to the contents of the flask, and the volume was made up to 25 ml with de-ionized water. Phosphorus was then measured colourimetrically using stannus chloride method (Jackson, 1958). Available P in soil was extracted by 0.5 N NaHCO_3 at pH 8.5, according to Olsen's procedure and determined colourimetrically using stannus chloride (Jackson, 1958).

RESULTS AND DISCUSSION

Changes in carbon contents, i.e. total humified, extracted, and its distribution within humic substances in the tested soil, as affected by the application of the organic material and phosphate compounds, are listed in Table (3). In the treatments having no organic materials addition, all forms of native carbon diminished

Table 3. Content of organic carbon forms extracted from the soil amended with organic material and insoluble phosphate compounds.

Sampling time (Days)	Without organic material						With organic material							
	Total humified carbon %	Extracted humified carbon %	Index	Humic acid (HA)		HA/FA ratio	Total humified carbon %	Extracted humified carbon %	Index	Humic acid (HA)		HA/FA ratio		
				(H)	% of total humified carbon					(H)	% of total humified carbon			
Without Phosphorus Addition														
15	1.210	0.399	100.00	67.02	19.33	13.65	1.42	1.502	0.570	72.80	62.05	19.40	18.55	1.04
30	1.198	0.393	98.50	67.20	19.20	13.60	1.41	1.617	0.667	85.19	58.72	21.67	19.61	1.11
60	1.149	0.345	86.47	69.97	18.27	11.76	1.55	1.739	0.738	94.25	57.57	23.24	19.19	1.21
90	1.138	0.337	84.47	70.39	17.40	12.21	1.42	1.650	0.783	100.00	57.66	25.10	17.24	1.45
135	1.120	0.322	80.70	71.25	17.20	11.55	1.49	1.490	0.596	76.12	60.00	24.15	15.85	1.52
180	1.116	0.314	78.70	71.86	17.02	11.12	1.53	1.470	0.579	73.95	60.58	23.79	15.63	1.52
Basic Slag														
15	1.210	0.399	100.00	67.09	19.25	13.66	1.41	1.529	0.610	73.05	60.10	20.35	19.55	1.04
30	1.200	0.395	98.99	67.08	19.30	13.62	1.42	1.662	0.680	81.44	59.09	21.39	19.52	1.10
60	1.177	0.355	88.57	69.84	17.66	12.50	1.41	1.802	0.775	92.81	56.99	22.41	20.60	1.09
90	1.148	0.341	85.46	70.30	17.45	12.25	1.42	1.836	0.835	100.00	56.87	22.80	20.33	1.12
135	1.128	0.330	82.71	70.74	17.16	12.10	1.42	1.645	0.680	81.44	58.66	22.60	18.74	1.21
180	1.126	0.321	80.45	71.49	16.99	11.52	1.47	1.616	0.640	76.65	60.40	21.90	17.70	1.24
Rock Phosphate														
15	1.210	0.399	100.00	67.02	19.33	13.65	1.42	1.520	0.591	73.69	61.12	19.68	19.00	1.05
30	1.198	0.393	98.50	67.20	19.20	13.60	1.41	1.634	0.672	83.79	58.87	21.41	19.90	1.07
60	1.169	0.350	87.72	70.06	17.60	12.34	1.43	1.760	0.745	92.89	57.67	22.64	19.69	1.15
90	1.141	0.339	84.96	70.29	17.50	12.21	1.43	1.871	0.802	100.00	57.13	23.75	19.11	1.24
135	1.123	0.326	81.70	70.97	17.30	11.21	1.47	1.596	0.640	79.80	59.90	22.85	17.25	1.32
180	1.121	0.318	79.70	71.63	17.10	11.27	1.52	1.541	0.612	76.31	60.29	22.54	17.17	1.31

with incubation time, due to mineralization process that took place by microorganisms resulting in carbon loss to atmosphere in the form of CO_2 . The tabulated data also indicate that the decrease in humified carbon of the soil amended with inorganic phosphate compounds was lower than that of the unamended soil. However, in the soil supplemented with organic material, content of total humified-, extracted-, and humic acid-carbon showed gradual increase to reach peaks within 90 days, thereafter, started to decline. Such pattern is ascribed to the conversion of carbon from non-humic raw material to humic matter during the first phase, then its mobilization to gaseous CO_2 in the latter phase. Phosphate application resulted in higher contents of humified carbon forms in soil, where the basic slag surpassed the rock phosphate. This is attributed to the stimulatory action of P on soil microorganisms contributing to the humification process of the raw organic material introduced.

Results of Table (3) also show that humic acid predominated over fulvic acid in all soil treatments. Such finding agrees with those obtained by Khalifa (1979) and Khalil and Amer (1986). The ratio of humic to fulvic acid (HA/FA) was more than one throughout (Table 3). It decreased by the addition of each of organic material and inorganic phosphate compounds. The basic slag reduced the HA/FA ratio more than did the rock phosphate. One or more of three possibilities might contribute to the diminution of HA/FA ratio, namely, rate of fulvic acid formation exceeds that of humic acid, retarded conversion of fulvic to humic acid, and/or encouraged oxidation of humic acid. High levels of phosphates might support the first and third instances via stimulated microbial activity, whilst formation of stable fulvic-phosphate complexes could explain the second case. The solvent action of fulvic acid on various minerals has been demonstrated by several investigators (Deuel, 1960; Kononova *et al.* 1964; Sinha, 1972; Kodama and Schnitzer, 1973; Schnitzer and Kodama,

1976). These results assume a practical significance in view of the fact that fulvic acid is major among the humus substances present in soil solution and also represents the initial product of humification of plant residues in soils.

Humic content (Table 3) revealed slight promotion by advancing time of incubation. The increase in humic content does not reflect any absolute increments, but due rather to diminution in both humic and fulvic acid contents. Application of each of the mineral phosphate compounds and organic material reduced the humic component.

Changes of humified P (associated with humic substances, namely, organo-metallic phosphates) and mobilized P in soil during the humification course of organic matter are illustrated in Figs. (1 & 2). Both contents of humified and soluble P were augmented with the application of each of organic material and insoluble phosphate compounds. Peaks of P levels were generally observed after 60-90 days of incubation.

The increase of available P could be explained by the production of CO_2 and thus formation of H_2CO_3 , during organic matter breakdown, which contributes to phosphate solubility. Of equal or possibly even greater significance is the evidence that compounds resulting from organic matter decomposition, particularly organic acids, are active in rendering P more available. In this connection, Jensen (1917) reported that water extracts of decomposed plant materials were effective in dissolving phosphate in soil, likewise, humic extracts obtained from soil or composts enhance the mobilization of P in soil or increase its availability to plants. Application of basic slag, in the present work, gave greater amounts of each of humified and soluble P than did the rock phosphate (Figs. 1 & 2). This result may be referred to the presence of higher alumina content in the rock phosphate than in the basic slag (Table 2). Such

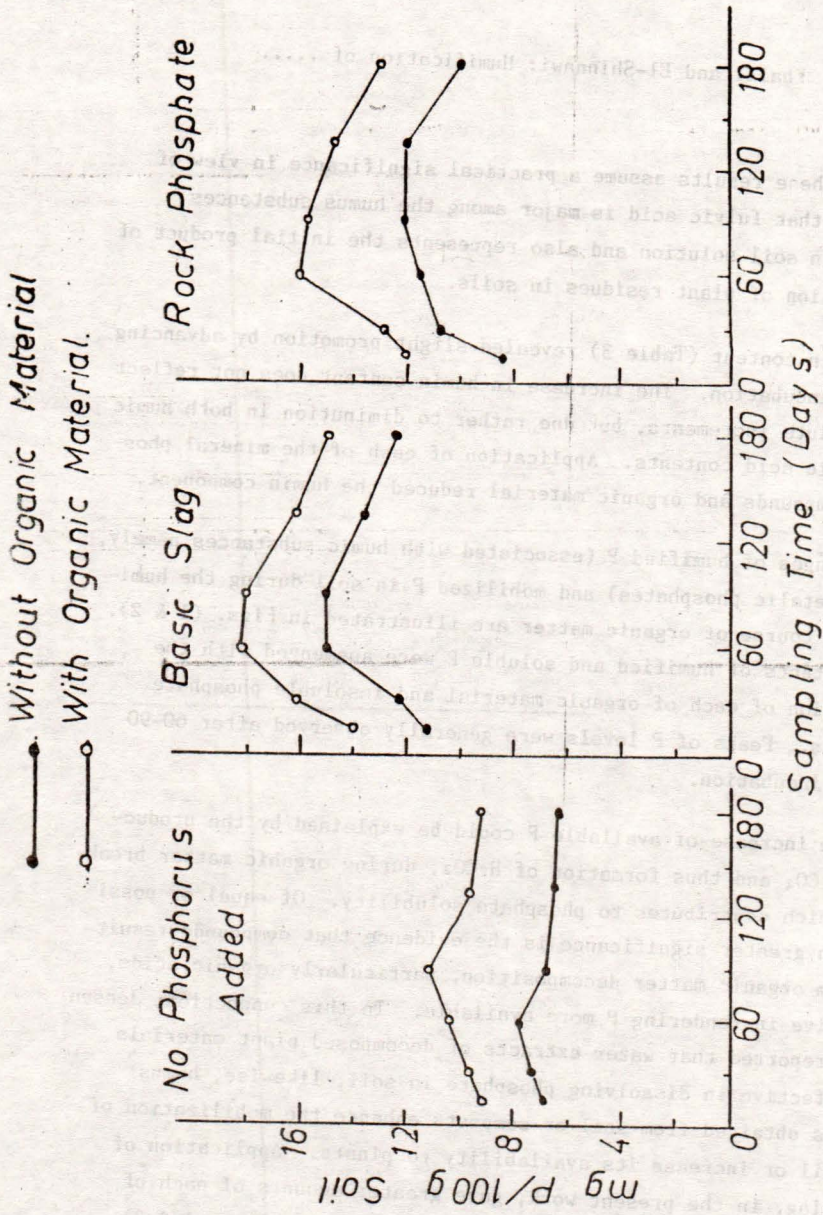


Figure 1. Changes in humified P in soil as affected by organic addition and source of mineral phosphate applied.

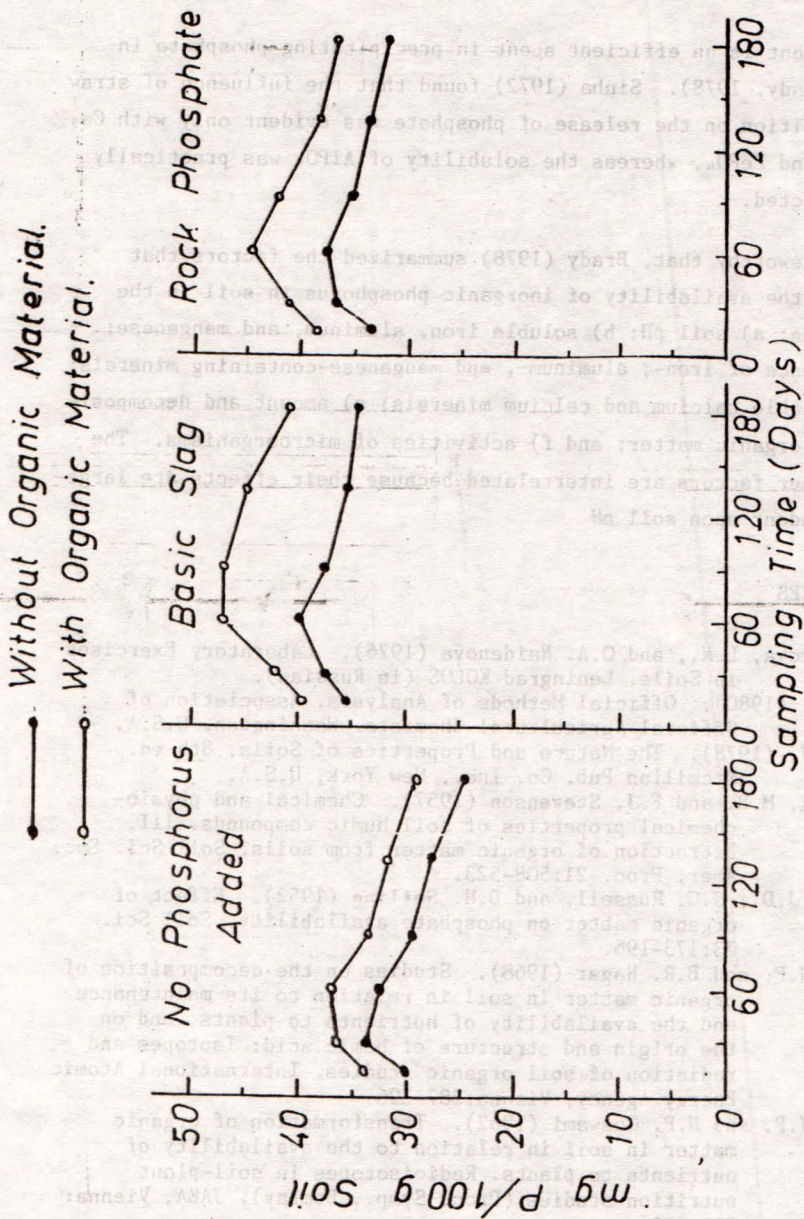


Figure 2. Mobilization of P in soil as affected by the organic addition and source of mineral phosphate applied.

constituent is an efficient agent in precipitating phosphate in soil (Brady, 1978). Sinha (1972) found that the influence of straw decomposition on the release of phosphate was evident only with $\text{Ca}_3(\text{PO}_4)_2$ and FePO_4 , whereas the solubility of AlPO_4 was practically not affected.

Noteworthy that, Brady (1978) summarized the factors that control the availability of inorganic phosphorus in soil in the following: a) soil pH; b) soluble iron, aluminum, and manganese; c) presence of iron-, aluminum-, and manganese-containing minerals; d) available calcium and calcium minerals; e) amount and decomposition of organic matter; and f) activities of microorganisms. The first four factors are interrelated because their effects are largely dependent upon soil pH

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