

CHANGES IN CARBON, NITROGEN, AND PHOSPHORUS CONTENTS
OF ORGANIC MATTER HUMIFIED IN DIFFERENT ARID SOILS

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التغيير فى محتوى الكربون والنترجين والفسفور أثناء تحليل
المادة العضوية فى أراضى جافة مختلطة

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مخلص البحث

تم دراسة التغيير فى محتوى الكربون والنترجين والفسفور فى مستخلص
المادة الدبالية من أراضى : طينية غير ملحية (pH ٧,٩) وطينية طميية ملحية
(pH ٨,٦) ورملية (pH ٧,٤) أثناء تحليل تين البرسيم المضاف إليها عند
٦٠% من قدرة الأرض على حفظ الماء والتحصين على درجة حرارة (٢٠ ± ٢ م°)
لعنة ١٨٠ يوم .

وقد أوضحت النتائج زيادة محتوى الكربون لحامض الهيوميك مع الوقت
حتى ٩٠ - ١٢٠ يوم حيث تناقص بعد ذلك فى جميع الأراضى . أما محتوى
الكربون لحامض الفلتيك فقد نقص مع زيادة زمن التحصين . أما نسبة حامض
الهيوميك إلى حامض الفلتيك كانت كالتالى :

الأرض الطينية الغير ملحية < الأرض الطينية الطميية الملحية < الأرض الرملية .
وقد ساد حامض الهيوميك على حامض الفلتيك فى الأراضى الطينية الغير ملحية
والطينية الطميية الملحية ، فى حين أن حامض الفلتيك قد ساد فى الأرض
الرملية .

وجد أن محتوى الأرض الطينية الغير ملحية من النترجين والفسفور كان
أعلى من كل من الأرض الطينية الطميية الملحية والأرض الرملية . وقد احتفظت
الأرض الرملية بالمركز الثانى والثالث للنترجين والفسفور على التوالى . كما
وجد أن المحتوى النترجيني للمادة الدبالية المستخلصة كان يقل مع زيادة زمن
التحصين لكل الأراضى المستخدمة ، فى حين أن محتواها من الفسفور كان
يزيد حتى يصل الى قمة تتوقف على خواص الأرض ثم يقل بعد ذلك .

ABSTRACT

Changes in C, N, and P contents of organic matter extracted from alluvial non-saline clay (pH 7.9), alluvial saline clay loam (pH 8.6) and loamy sand (pH 7.4) soils during humification of clover hay added were studied at moisture content of 60% WHC and mesophilic incubation ($20 \pm 2^\circ\text{C}$) along 180 days.

Carbon content of humic acid showed promoting values with time up to 90-120 days, then declined in all soils tested. Fulvic acid-carbon decreased with incubation time in all cases. Order of HA:FA ratio was: non-saline > saline > sandy soil. Humic acid surpassed fulvic acid in both non-saline and saline soils, but an opposite trend was obtained by the sandy soil.

The non-saline soil kept the uppermost N and P contents of the extracted humified matter. The sandy soil occupied the second and third positions for N and P respectively. Nitrogen content of the humifying matter diminished with incubation time, whilst phosphorus revealed increases to a peak depended on soil properties, then slightly diminished.

INTRODUCTION

The decomposition of plant and animal remains in soil constitutes a basic biological process in that carbon is recirculated to the atmosphere as CO_2 , nitrogen is made available as NH_4^+ and NO_3^- , and other associated elements (P, S, Fe ... etc) appear in forms required by higher plants. In the process, some of the C and other elements is assimilated into microbial cells (the soil biomass) and part is converted into stable humus. Some of the native humus is mineralized concurrently; consequently, total organic matter content is maintained at some steady-state level characteristic of the soil and management system (Stevenson, 1982).

The diverse role of physical, chemical, and biological properties of the soil in processes of humus formation is attributable,

on the one hand, to the effect on microbiological processes and hence on the processes of new-formation/decomposition of organic matter. On the other hand, there can be no doubt about the important influence of soil characteristics on the fixation of humic substances in various forms of organo-mineral compounds and therefore on their retention in the soil (Kononova, 1966).

The present work was designed to study the changes in the contents of C, N, and P of a raw organic material during its humification in three arid soils of Egypt, namely; alluvial non-saline, alluvial saline, and sandy.

MATERIALS AND METHODS

~~Samples of three arid soils were collected from the surface layer (0-30 cm) of the following locations in Egypt:~~

1. Alluvial non-saline (Torrifluvents), from the Experimental Farm of the Faculty of Agriculture, Shebin El-Kom.
2. Alluvial saline (Salic Torrifluvents), from Sakha.
3. Sandy (Torripsamments), from Quesna.

Soil samples were air-dried, ground to pass through a 2-mm sieve, and thoroughly mixed. Routine analysis for these soils was undertaken according to the methods described by Jackson (1958); data are presented in Table 1 (a & b).

Two sets of 200-ml polypropylene containers were assigned to each soil. 100 g of soil crumbs were placed in each container. Finely pulverized clover hay (organic carbon 49.4%, nitrogen 0.84% & phosphorus 0.12%) was employed as a source of organic supplement. To each container of one set, 3 g of the clover hay were applied and entirely mixed with the soil crumbs. The other set of soil

Table 1 . Analytical data of the investigated soils

a) Physical properties

Soils	Organic matter %	CaCO ₃ %	Particle size distribution (%)			Textural grade
			Sand	Silt	Clay	
Alluvial non-saline	2.15	2.80	27.02	27.02	45.96	Clay
Alluvial saline	0.96	3.09	38.11	23.58	38.31	Clay loam
Sandy	0.25	0.51	87.20	2.12	10.68	Loamy sand

b) Chemical properties

Soils	pH (1:2.5)	E.C.** m mho/cm	C.E.C. 100 g	Total N %	Total P %	Soluble ions (meq/100 g)**							
						Cations			Anions				
						Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	Cl ⁻	HCO ₃ ⁻	CO ₃ ⁼	SO ₄ ⁼
Alluvial non-saline	7.90	0.44	28.60	0.10	0.09	0.80	0.45	1.12	0.33	0.80	0.95	-	0.95
Alluvial saline	8.60	7.60	26.20	0.06	0.07	0.75	1.00	1.70	0.64	1.25	1.13	-	1.71
Sandy	7.40	0.30	5.10	0.03	0.04	0.07	0.01	0.03	0.03	0.06	0.04	-	0.04

* Soil: water suspension

** In soil paste extract.

containers was left without organic material addition. Soils contained of both sets were amended with an activating nutrient mixture (1 mg superphosphate, 0.05 mg potassium sulphate, and 0.01 mg urea to each container). 10 ml of fresh fertile soil-water suspension (1:5) were added to each container to serve as inoculum. Moisture content of the soil was brought to 60% of the water-holding capacity by deionized water. All treatments were run in duplicate. 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, N, & 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 method (Alexandrova and Naidenova, 1976).

The samples were then subjected to the following technique:

50 g of soil sample were placed in a 1000-ml polyethylene bottle, then 250 ml of freshly prepared 0.5 N NaOH were added as extractant, and 2.5-ml of concentrated Sn Cl₂ were also added (Choudhri and Stevenson, 1957). The mixture was shaken by end-over-end shaker for one hour, then left to stand over night (16-18 h) at room temperature. The suspension was shaken vigorously and 5 g of Na₂SO₄ 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 substance-carbon were determined by means of Walkely and Black method (Jackson, 1958) taking in consideration the recommendation of Kononova (1966).

For estimation of total nitrogen and total phosphorus of the humifying matter extracted from soil, 25 ml of the supernatant mentioned above were pipetted into a 100-ml Erlenmeyer flask which was then placed on a boiling-water bath and left to be evaporated to dryness. 5 ml H_2SO_4 conc. + 1 ml $HClO_4$ conc. were added to the contents of each flask, then the volume was made up to 25 ml with deionized water. Total N in the supernatant was determined by Kjeldahl procedure. Total P was measured colourimetrically using stannous chloride method (Jackson, 1958).

RESULTS AND DISCUSSION

A. Carbon changes:

Changes in the carbon content, i.e. total humified, extracted, and its distribution among humic substances in the soil tested are listed in Table 2 (a through c). In the treatments having no organic addition, all forms of native carbon diminished with incubation time, due to mineralisation that took place by microorganisms resulting in carbon loss to the atmosphere in the form of CO_2 . However, in the soils treated with organic material, content of total humified-, extracted-, and humic acid-carbon showed gradual increases to reach peaks within 60-120 days, thereafter started to decline. Such pattern is ascribed to the conversion of carbon from non-humic raw material into humic matter during the first phase, then its decomposition to the gaseous CO_2 form in the latter phase. Length of each phase depended on soil type, i.e. order of the first phase was: saline > non-saline > sandy soils. The improper chemical characteristics of the saline soil, particularly salt content and pH value (Table 1b), stood behind its position via inhibition of microbial activity (El-Shinnawi *et al.*, 1976). The heavy texture of the non-saline soil (Table 1a) played a role in delaying the

Table 2 . Changes in organic carbon and its content of the humic substances

a) of the alluvial non-saline soil.

Sampling time (days)	Total humified carbon (%)	Extracted humified carbon (%)	Index	Carbon content of the humic substances (%)			HA/FA
				Humic	HA*	FA**	
Without organic material							
15	1.210	0.399	100.00	67.01	19.34	13.65	1.42
30	1.198	0.393	98.50	67.20	19.20	13.60	1.41
45	1.158	0.365	91.48	68.48	18.65	12.87	1.45
60	1.149	0.345	86.47	69.97	18.27	11.76	1.55
90	1.138	0.337	84.47	70.39	17.40	12.21	1.42
120	1.127	0.326	81.70	70.74	17.40	11.86	1.47
150	1.125	0.320	80.20	71.56	17.07	11.37	1.50
180	1.116	0.314	78.70	71.86	17.02	11.12	1.53
With organic material							
15	1.502	0.570	72.80	62.05	19.40	18.55	1.04
30	1.617	0.667	85.19	58.72	21.67	19.61	1.11
45	1.725	0.697	89.02	59.58	21.89	18.53	1.19
60	1.739	0.738	94.25	57.57	23.24	19.19	1.21
90	1.850	0.783	100.00	57.66	25.10	17.24	1.45
120	1.500	0.634	80.97	57.75	24.71	17.54	1.41
150	1.480	0.587	74.97	60.36	23.91	15.73	1.52
180	1.470	0.579	73.95	60.58	23.79	15.63	1.52

* HA = Humic acid

** FA = Fulvic acid

Table 2 . (Cont.)

b) of the alluvial saline soil.

Sampling time (days)	Total humified carbon (%)	Extracted humified carbon (%)	Index	Carbon content of the humic substances (%)			HA/FA
				Humin	HA	FA	
Without organic material							
15	0.550	0.180	100.00	67.27	18.00	14.73	1.22
30	0.535	0.176	97.78	67.10	17.94	14.96	1.20
45	0.520	0.162	90.00	68.85	17.88	13.27	1.35
60	0.513	0.157	87.22	69.40	17.15	13.45	1.28
90	0.480	0.146	81.11	69.58	16.67	13.75	1.21
120	0.465	0.140	77.76	69.89	16.13	13.98	1.15
150	0.458	0.138	76.67	69.87	15.94	14.19	1.12
180	0.424	0.127	70.56	70.05	15.27	13.68	1.19
With organic material							
15	0.860	0.263	91.96	69.47	15.39	15.14	1.02
30	0.867	0.271	94.75	68.71	15.78	15.51	1.02
45	0.900	0.271	94.75	69.83	15.34	14.83	1.03
60	0.921	0.273	95.45	70.28	15.35	14.37	1.07
90	0.926	0.286	100.00	69.12	16.35	14.53	1.13
120	0.944	0.275	96.15	70.85	17.06	12.09	1.41
150	0.931	0.262	91.61	71.84	16.73	11.43	1.46
180	0.910	0.252	88.11	72.22	16.64	11.14	1.49

Table 2. (Cont.)
c) of the sandy soil.

Sampling time (days)	Total humified carbon (%)	Extracted humified carbon (%)	Index	Carbon content of the humic substances (%)			HA/FA
				Humin	HA	FA	
Without organic material							
15	0.140	0.069	100.00	50.71	14.29	35.00	0.41
30	0.134	0.067	97.10	50.00	14.93	35.07	0.43
45	0.120	0.063	91.30	47.50	17.50	35.00	0.50
60	0.115	0.058	84.06	49.57	20.64	29.79	0.69
90	0.106	0.052	75.36	50.94	20.75	28.31	0.73
120	0.101	0.048	69.57	57.48	20.79	26.73	0.78
150	0.096	0.040	57.97	58.33	19.79	21.88	0.90
180	0.086	0.038	55.07	55.81	20.93	23.26	0.90
With organic material							
15	0.340	0.147	69.67	56.76	19.12	24.12	0.79
30	0.398	0.182	86.26	54.27	21.11	24.62	0.86
45	0.450	0.192	92.89	56.44	21.11	22.45	0.94
60	0.480	0.211	100.00	56.04	22.08	21.88	1.01
90	0.460	0.201	95.26	56.30	22.83	20.86	1.09
120	0.450	0.185	87.68	58.99	21.68	19.33	1.12
150	0.413	0.180	85.31	59.42	21.44	19.11	1.12
180	0.390	0.172	81.52	60.03	21.28	18.69	1.14

first phase through two possible actions, namely, lowering the level of aeration in the microenvironment and inactivating microbial enzymes by binding them to clay particles (Burns, 1986). Situation of the sandy soil is attributed to its loose texture which provides freely gaseous exchange and makes minimum restriction for the biochemical processes in the soil medium.

Fulvic acid-carbon showed fluctuating values tending to decrease, generally, with time in all variables. Ratio of humic to fulvic acids implied progress by advancing the incubation time, which means polymerization of humic acid at the expense of fulvic one. The non-saline soil attained the highest HA:FA ratio throughout and followed by the saline and the sandy soils respectively. This trend is a direct reflection of soil properties on the rate of humic acid formation from fulvic acid as catalyzed by microbial enzymes. The non-saline soil, originally rich and balanced in nutrients, as well as harbouring abundant numbers and kinds of microorganisms; and the sandy soil, the poorest in such properties, kept the extreme positions.

Humic acid surpassed fulvic acid in both non-saline and saline soils either with or without organic material addition, but in the unamended sandy soil, fulvic acid predominated over humic acid. This is due to the originally poor nutritional status of the sandy soil which restricts its microbial activity on converting the fulvic acid into humic acid. Moreover, the results shown by both the non-saline and saline soils might be correlated with clay content of the soil (Table 1a), since the clay fraction plays a protective action for humic acid by forming less biodegradable organo-clay complexes (Martin and Haider, 1986).

Humic content was highest in the saline soil and followed by the non-saline and the sandy soils respectively. This is attributed

to salt content of the soil which induces the formation of humates (humic acid salts) (Schnitzer and Kodama, 1977). Content of humin in the control treatments showed relatively slight promotion with time. This does not reflect any absolute increments, but due rather to diminution in both humic and fulvic acids. No definite trend could be specified for the changes brought about in the organic material-amended soils.

B. Nitrogen changes:

Introduction of organic material into the soils increased the total nitrogen level of the extracted humic fraction (Fig. 1). Contents of extracted nitrogen showed linear declination with time, due to mineralisation of the organic nitrogenous compounds leading to the liberation NH_3 , which might be lost via volatilization either during incubation, as affected by the above-neutral reaction of the soils, or during the extraction technique.

The non-saline soil possessed the highest N levels and followed by the sandy and the saline soils respectively (Fig. 1). The original low N content in the saline soil besides its high pH value (Table 1b) which enhances volatilization of NH_3 , are the reasons behind its least N content among the soils tested.

The jump accomplished for N contents in the organic material-supplemented soils was highest for the non-saline soil and lowest for the saline soil (Fig. 1). This is referred to the chemical properties of each soil which suit the acting microflora in the first soil and unfavour it in the second (El-Shinnawi, 1975). The sandy soil occupied intermediate position due to its physical properties which permit good aeration and thus hasten the breakdown of the added organic material. This is ascertained by the rate of decrease in N content of the soil studied (slope of lines in Fig. 1).

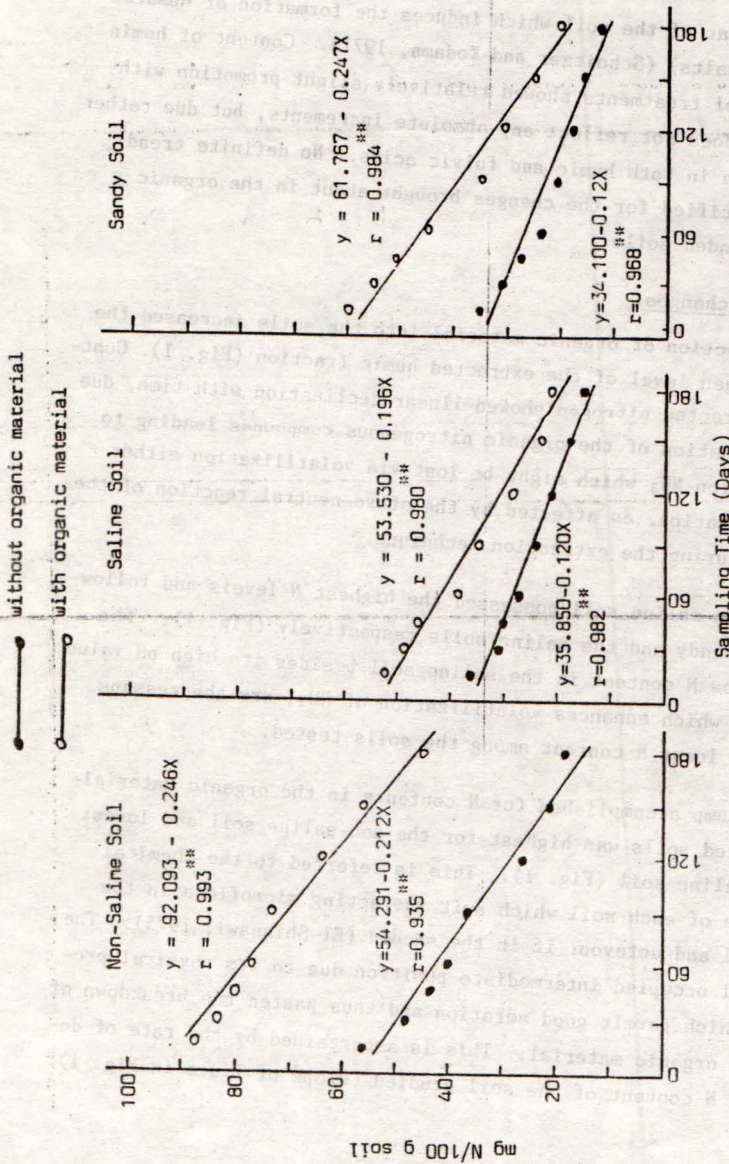


Figure 1. Changes in the extracted total nitrogen of the soils tested.

** LSD at level 1%.

C. Phosphorus changes:

Values of extracted phosphorus of the soils under consideration revealed smooth peaks within 90-120 days of incubation (Fig. 2), corresponding to the changes in the humified carbon and particularly associated with the alterations of the humic acid (Table 2 a to c). It is well established that humic acid is major among the factors affecting transformation of phosphorus in soil (Deuel, 1960; Barrow, 1961; Dormaar, 1963; and Harter, 1977).

Again the physical and chemical characteristics of the soils examined affected the P amounts extracted, when the non-saline soil excelled the saline soil; the sandy soil was the least (Fig. 2).

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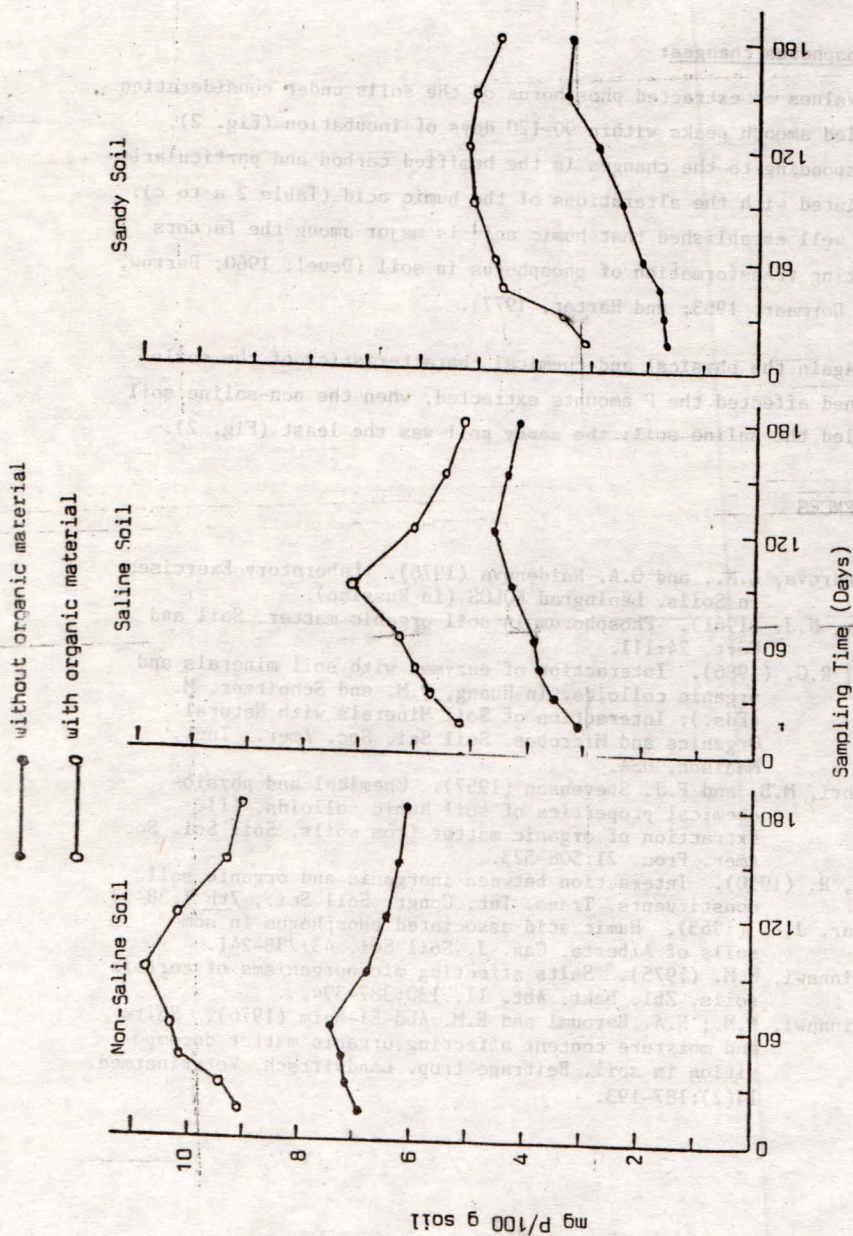


Figure 2. Changes in the extracted phosphorus of the soils tested.

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