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EFFECTS OF SALTS ON DECOMPOSITION OF PLANT RESIDUES

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Abstract

EFFECT OF SALTS ON DECOMPOSITION OF PLANT RESIDUES.

Decomposition of plant residues added to soils was studied in the absence and presence of salts in incubation experiments at 29 ± 1°C and 60% W.H.C. The evolved CO_2 and organic carbon content of the treated soil were determined periodically for 28 days. Clay and calcareous soils evolved higher quantities of CO_2 than either clay loam or sandy soil. Clover straw was the most easily decomposable plant material, followed by corn stalks, cotton stalks and wheat straw being the least decomposable. Using the clay soil and clover straw (1%), CO_2 evolution increased in the presence of Na_2CO_3 and $CaCO_3$ and was depressed by NaCl, Na_2SO_4, $CaCl_2$, $MgCl_2$, $MgSO_4$ (25 meq/100 g soil), $CaSO_4$ and $MgCO_3$ (250 meq/100 g soil). Generally, the rate of decomposition was depressed progressively with increased concentrations of salts. The rate of CO_2 evolution decreased with increased additions of clover straw. The changes in soil organic carbon agreed with CO_2 evolution under all treatments.

INTRODUCTION

When plant or animal residues fall upon or are incorporated into the soil, they are subjected to microbial decomposition. The decomposability of these organic materials, in the soil, is affected by many factors [1–3]. Several workers agree that the salinity of soil decreases the numbers of micro-organisms and inhibits some of their activities [4–9]. The effect of salts on decomposition of organic matter in soil has not been sufficiently investigated [8]. The present work deals with the decomposition of plant residues in salt-affected soils.

MATERIAL AND METHODS

Soils

Samples of four different Egyptian soils were collected at a depth of 0 to 30 cm. These soils were sandy, clay loam, calcareous sandy loam and clay.

Each soil was leached until freed from excess salts, air-dried, sieved through a 2-mm sieve, and the fine material was mixed thoroughly and stored in polythene bags. Some properties of these soils, after leaching, were determined according to Black and co-workers [10], and are recorded in Table I.

TABLE I. SOME CHARACTERISTICS OF THE USED SOIL SAMPLES (AFTER LEACHING SOLUBLE SALTS)

Property	Sandy	Clay loam	Calcareous	Clay
Organic carbon (ppm)	75	7278	6609	5272
Total nitrogen (ppm)	6	844	853	751
Total carbonates (%)	0.6	14.8	35.5	8.2
Clay (%)	0.0	36.2	27.0	45.2
Silt (%)	0.5	40.2	20.6	24.5
Sand (%)	99.5	23.5	52.6	30.3
pH (1 : 5 H_2O suspension)	7.6	8.2	8.3	7.8

Plant residues

Cotton stalks, corn stalks, wheat straw and clover straw were used. Samples of each plant material were air-dried and ground to pass through a 60-mesh sieve. Chemical analysis of these substances showed that they contain from 38–39% organic carbon. The nitrogen contents of cotton and corn stalks and wheat straw were about 0.4–0.5% and that of clover straw was 2.2%.

Salts

The readily soluble salts, NaCl, $CaCl_2$, $MgCl_2$, Na_2SO_4, $MgSO_4$ and Na_2CO_3, were used in concentrations ranging between 0 and 75 meq/100 g soil. The relatively insoluble salts, $CaSO_4$, $MgCO_3$ and $CaCO_3$, were used in concentrations that varied from 0 to 500 meq/100 g soil.

Measuring rate of decomposition of plant residues

The decomposition of plant residues added to soils was measured by determining CO_2 evolution at intervals for 28 days.

The closed technique with intermittent aeration and the absorption of evolved CO_2 in standard NaOH solution was used [10,11]. The experiments were conducted in a constant temperature room (29 ± 1°C) using 100 g portions of the soil with and without plant material and salts. Moisture content was adjusted to 60% W.H.C. Every treatment was carried out in triplicate.

RESULTS AND DISCUSSION

Table II shows the average carbon evolved as CO_2 from the soils amended with 1% plant residues in the absence of salts. The extent of decomposition of each plant material differed from one soil to another. Clay and calcareous soils involved higher amounts of CO_2 than either the clay loam or the sandy soil. Clover straw was the most readily decomposable plant residue used, with an almost constant rate during the 28 days incub

TABLE II. AVERAGE CUMULATIVE CARBON EVOLVED AS CO_2 FROM SOILS AMENDED WITH 1% PLANT RESIDUES IN mg/100 g SOIL

Soil	Plant residues added	Days of incubation				
		4	8	12	20	28*
	Control	1.9	3.3	4.8	7.6	10.5
	Cotton stalks	7.8	14.5	19.8	27.4	33.0
Sandy	Clover straw	13.4	26.9	38.6	58.9	74.8
	Corn stalks	9.1	15.9	20.8	29.2	37.0
	Wheat straw	5.0	8.2	10.5	14.7	17.4
	Control	2.0	4.1	6.4	9.9	12.7
	Cotton stalks	10.8	21.6	30.7	44.7	53.4
Clay loam	Clover straw	11.4	23.0	36.5	54.5	65.5
	Corn stalks	9.6	21.4	31.7	47.9	58.8
	Wheat straw	7.0	15.8	24.2	36.1	43.1
	Control	4.1	7.3	10.3	14.7	18.1
	Cotton stalks	11.1	23.7	38.3	59.0	73.1
Calcareous	Clover straw	13.0	27.0	44.9	66.7	85.4
	Corn stalks	12.4	24.7	39.6	61.4	78.9
	Wheat straw	9.5	20.5	32.8	49.1	59.9
	Control	0.9	1.9	3.6	6.8	9.5
	Cotton stalks	9.3	21.1	32.3	50.3	63.8
Clay	Clover straw	12.6	25.7	40.7	68.7	91.1
	Corn stalks	10.0	21.1	33.2	55.4	73.9
	Wheat straw	8.3	18.9	27.1	39.5	49.0

* $LSD_{(0.05)}$: plant residue = 1.1
$LSD_{(0.05)}$: soil = 1.1
$LSD_{(0.05)}$: plant residues with soil = 2.2.

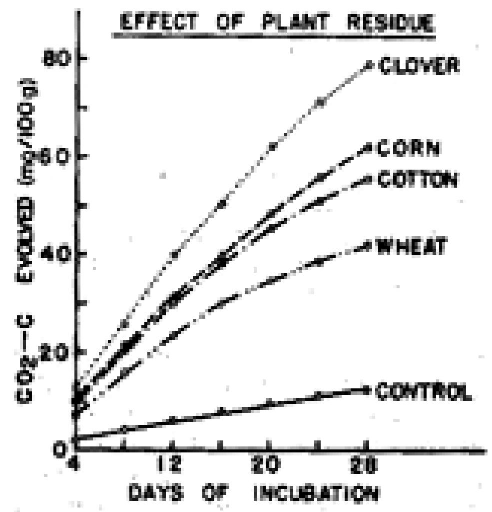

FIG.1. Effect of type of added plant residue on cumulative CO_2 evolution (average of the four soils used).

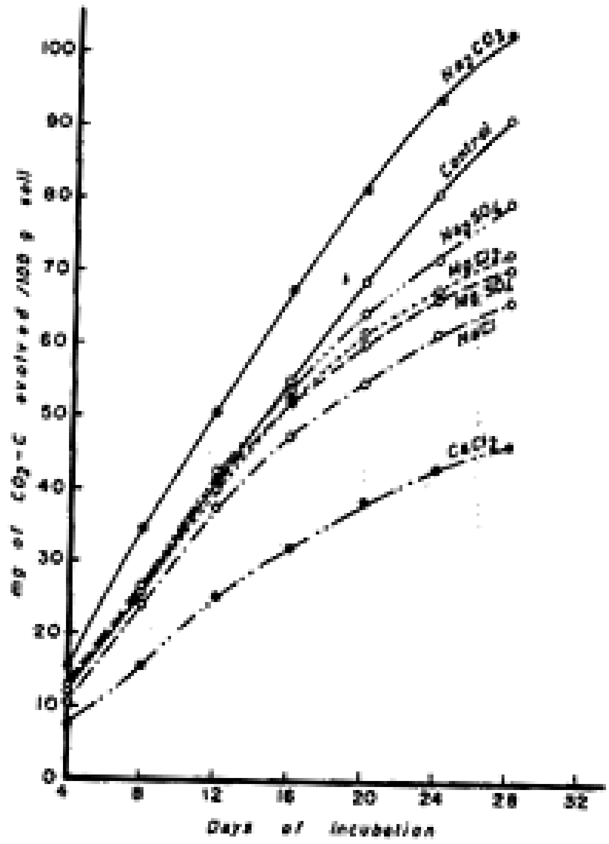

FIG.2. Effect of readily soluble salts (25 meq/100 g soil) on the cumulative CO_2-C evolved from the clay soil treated with 1% clover straw.

clover straw, then cotton stalks and the least was wheat straw. The latter three plant materials, especially wheat straw, showed diminishing decomposition rates with time. The differences in composition and the C/N ratio of these plant residues might be responsible for the differences in both magnitude and rate of decomposition [1,2]. Statistical analysis of the results showed a highly significant interaction effect between the soil and the added plant residue. It is concluded that the type of soil as well as the kind of plant residue interdependently affected the rate and extent of the decomposition process.

The clover straw and the clay soil were chosen to study the effect of salts on the decomposition of added organic materials. The cumulative carbon evolved as CO_2 is illustrated in Fig.2 for NaCl, Na_2SO_4, Na_2CO_3, $CaCl_2$, $MgCl_2$ and $MgSO_4$, and in Fig.3 for $CaSO_4$, $MgCO_3$ and $CaCO_3$. The presence of salts either encouraged or discouraged the decomposition process depending on the type of the added salt; Na_2CO_3 and $CaCO_3$ favoured the decomposition of clover straw whereas the other salts slowed it down. The slow-down in the decomposition rate was greatest with $CaCl_2$ and $CaSO_4$. The salts that encouraged CO_2 evolution from the soil clover straw mixture did not

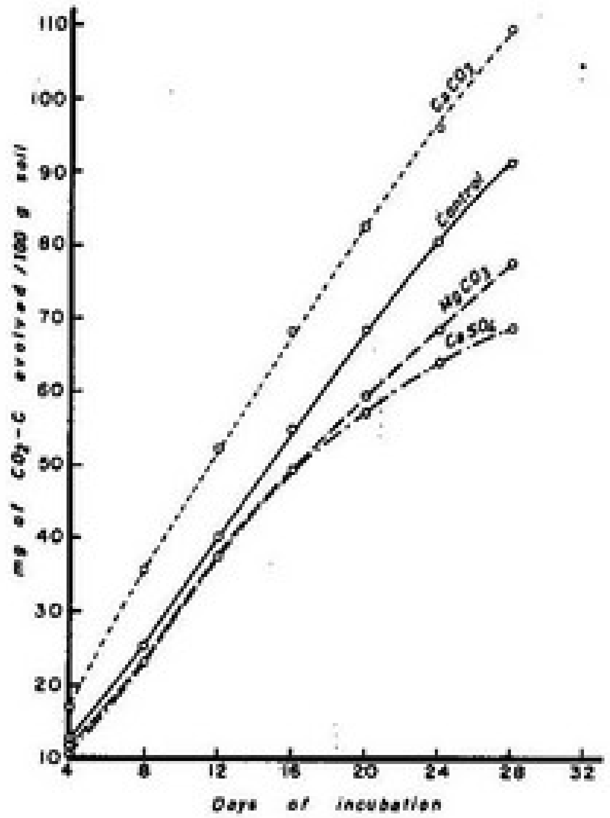

FIG. 3. Effect of the relatively insoluble salts (250 meq/100 g soil) on the cumulative CO_2-C evolved from the clay soil treated with 1% clover straw.

TABLE III. EFFECT OF VARIOUS SALT CONCENTRATIONS ON CUMULATIVE CARBON EVOLVED AS CO_2 FROM THE CLAY SOIL AMENDED WITH 1% CLOVER STRAW AFTER 28 DAYS OF INCUBATION IN mg/100 g SOIL

Salt concentration (meq/100 g)	Salts[a]					
	NaCl	$CaCl_2$	$MgCl_2$	Na_2SO_4	$MgSO_4$	Na_2CO_3
0.00	91.1	91.1	91.1	91.1	91.1	91.1
6.25	88.3	69.2	77.2	101.2	82.6	96.1
12.50	70.7	55.1	74.7	93.4	74.2	99.1
25.00	66.3	46.7	72.9	79.8	70.7	103.2
50.00	49.7	44.5	49.4	76.2	68.2	59.9
75.00	41.1	37.7	38.8	60.5	53.5	41.9

[a] $LSD_{(0.05)}$: salt = 1.0
$LSD_{(0.05)}$: concentration = 1.0
$LSD_{(0.05)}$: salt X concentration = 2.5.

TABLE IV. EFFECT OF VARIOUS SALT CONCENTRATIONS ON CUMULATIVE CARBON EVOLVED AS CO_2 FROM THE CLAY SOIL AMENDED WITH 1% CLOVER STRAW AFTER 28 DAYS OF INCUBATION IN mg/100 g SOIL

Salt concentration (meq/100 g)	Salt*		
	$CaSO_4$	$CaCO_3$	$MgCO_3$
0	91.1	91.1	91.1
50	77.8	92.6	86.1
100	75.6	94.1	84.1
250	68.9	109.3	77.7
500	65.1	99.4	66.2

* $LSD_{(0.05)}$: salt = 1.1
$LSD_{(0.05)}$: concentration = 1.4
$LSD_{(0.05)}$: salt × concentration = 2.4.

TABLE V. ORGANIC CARBON CONTENT OF THE TREATED CLAY SOIL IN mg/100 g SOIL

Incubation (days)	Soil only	Soil + 1% clover straw +			
		None	$CaCl_2$	NaCl	Na_2CO_3
0	569	944	945	945	945
4	564	920	931	925	916
12	560	870	894	882	865
20	558	842	875	851	831
28	556	802	842	830	787
Loss (% in 28 d)	2	15	11	12	17
CO_2-C evolved (mg in 28 d)	10	91	47	66	103

change the rate of the decomposition process, but those that discouraged it depressed that rate with time until the end of the 28 days' incubation period. In addition, a diminishing rate in the decomposition of clover straw with time occurred as the salt concentration increased. The magnitude of diminution was remarkably greater with the readily soluble salts than with the relatively insoluble salts. The data presented in Tables III and IV indicate that the evolved CO_2 differed significantly according to the salt added and its concentration.

In general, these findings are in agreement with the observations of earlier workers [6,8,9,12].

It seems that each salt had its own pattern of effect on the decomposition process as its concentration increased, $CaCl_2$ and Na_2CO_3 showing the most widely differing patterns of effect (Table III). The differences observed between the tested salts could be attributed to their effects on the chemical, physical and biological properties of the treated soil.

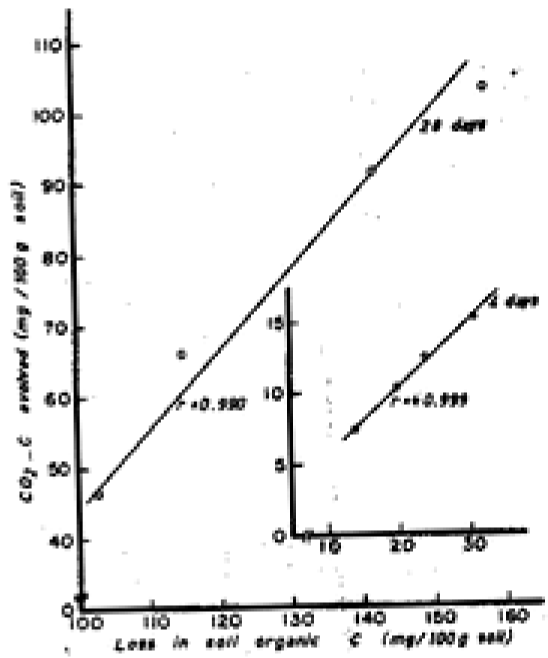

FIG.4. Relationship between CO_2 evolution and loss in soil organic matter after 4 and 28 days' incubation.

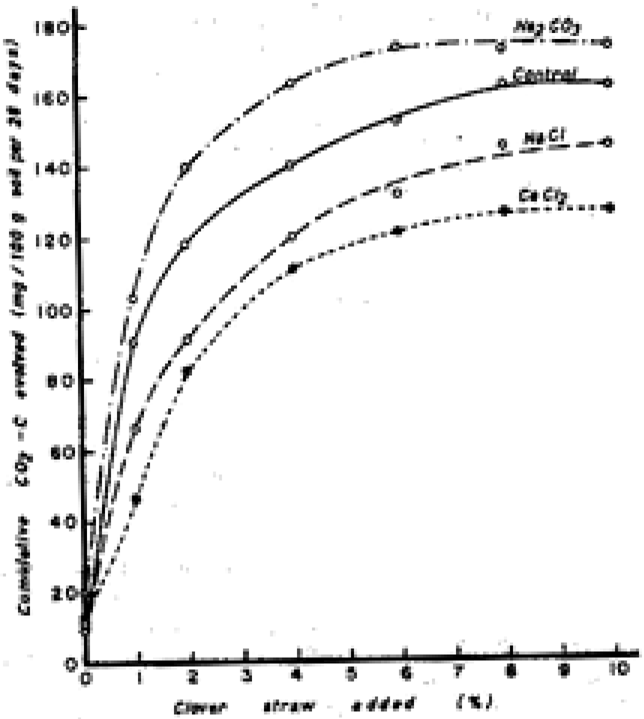

FIG.5. Effect of NaCl, $CaCl_2$ and Na_2CO_3 (25 meq/100 g soil) on cumulative CO_2-C evolution from clay soil treated with increasing amounts of clover straw.

The organic carbon content of the soil decreased gradually with time within the 28 days' incubation period. The loss in soil organic carbon correlated well with carbon dioxide evolution under all treatments (Table V and Fig.4).

Carbon dioxide evolved from the clay soil amended with increasing amounts of clover straw up to 10% in the absence and presence of NaCl, $CaCl_2$ and Na_2CO_3 (25 meq/100 g soil) is illustrated in Fig.5. The results indicate an initial rapid increase in CO_2 evolution followed by a diminishing increase with the increase in the amount of added clover straw. At 8–10% clover straw, no more CO_2 was evolved from the salt-treated or untreated soil. The general pattern of variation in the rate of decomposition resembled very much that which describes the change in the velocity of enzymatic reactions with respect to substrate concentration. CO_2 is one of the end products of organic matter decomposition in the soil, and the decomposition process is worked out through enzymatically controlled reactions. Therefore salts may or may not interfere with one or more of the enzymes engaged in the process of organic matter decomposition and CO_2 evolution.

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DISCUSSION

K.A. MALIK: Did you estimate exchangeable sodium after addition of salts.

A.S. ABDEL-GHAFFAR: No, I did not.

D.R. SAUERBECK: Did I understand correctly from your slides that you only presented gross rates of CO_2 production but did not subtract the CO_2 evolved from the untreated control soil in order to separate the CO_2 that was produced by the mineralization of the added material?

A.S. ABDEL-GHAFFAR: We did not subtract the CO_2 produced by the control from that produced by the treated soil.

D.R. SAUERBECK: Did you extend your incubation over more than 28 days, since up to this time the decomposition curves were still in the steep initial region? On extended incubation it may be expected that the curves will level off and gradually approach each other.

A.S. ABDEL-GHAFFAR: We did not extend the incubation period to more than 28 days.

D.R. SAUERBECK: With reference to the equal rates of CO_2 release irrespective of the amounts of organic material applied, do you not think that with your intermittent aeration of the incubation flasks, the oxygen may become a limiting factor in the samples with large additions of plant material?

A.S. ABDEL-GHAFFAR: I do not think that oxygen was the limiting factor, because if it was the oxygen, then we should have no differences between treatments, at least in the case of the large additions of plant material.

Z. FILIP: It can be assumed that the exchange reactions between soil mineral colloids (clays) and soil solution influenced the actual cation concentration in the soil solution, and therefore also the mineralization activity of micro-organisms. It would consequently be of interest to know the mineralogical composition of the clay fraction or at least the cation exchange capacity of the soils tested. Did you examine these values?

A.S. ABDEL-GHAFFAR: We did not determine the mineral composition of the clay fraction nor the cation exchange capacity. The salts used in this investigation are the salts responsible for salinity and alkalinity of soils, and if any exchange reactions take place following the addition of salts it is something that happens naturally.

W. FLAIG *(Scientific Secretary)*: Did you find different constituents in the humic fractions according to the different salts added?

A.S. ABDEL-GHAFFAR: We found differences in humic fractions following the addition of the salts but, due to the short period of incubation (28 days), the differences were small.

J.M.S. SSERUNJOJI: Do you know if persistent organic compounds like pesticides (e.g. DDT or dieldrin) would have similar effects as the degradation of plant residues?

A.S. ABDEL-GHAFFAR: The effect would depend upon the kind and the concentration of the pesticide. Usually, normal doses may not have any effect. In general, we notice an initial drop in activities of soil micro-organisms followed by stimulation.