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INVESTIGATIONS ON THE RÔLE OF ORGANIC MATTER IN PLANT NUTRITION

Part III. Influence of the Decomposition of Organic Matter on Soil Structure

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INVESTIGATIONS ON THE RÔLE OF ORGANIC MATTER IN PLANT NUTRITION.

Part III. Influence of the Decomposition of Organic Matter on Soil Structure.

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Although the importance of organic manures in agricultural practice has been recognised from the earliest times, it is yet only during recent years that their influence on the physical properties of the soil has been adequately recognised. Keen and Haines (1925) observed that moisture content is increased and resistance to the plough lowered as the result of liberal applications of organic manure. Kerr (1928) and, later, Baver (1930) noted that the absorptive capacity of soil for cations is improved by the presence of organic matter. Burr and Russell (1927) showed that organic matter helps to increase the plastic range and to decrease the toughness and solidity of soil. These and other observations bring into relief the beneficial effect of organic manures or the residual humus as admixed with the soil. They do not, however, throw any light on the influence of organic matter on the ultimate structure of inorganic particles constituting the soil. It is indeed believed that organic matter has no effect on the mechanical composition of the soil; that after its removal by either biological action or chemical oxidation, the soil reverts to its original physical structure.

In the course of an investigation on nitrogen transformations in swamp soils (Sreenivasan and Subrahmanyan, 1934) it was observed that those treated with organic manures tended to become increasingly heavy and sticky with the progress of decomposition. This observation combined with a few others such as increasing difficulty in dry-digesting such specimens for the estimation of nitrogen (Sreenivasan, 1934) suggested that the organic matter had brought about some permanent change in the physical texture of such soils. A systematic enquiry on the influence of decomposition of organic manures on the mechanical composition of soils was therefore undertaken.

Experimental.

Specimens of surface soil (red loam) from a virgin tract were collected and after being air-dried and ground to pass the 3 mm. sieve were filled into a number of glazed earthenware pots at 40 lbs. each. They were then treated as follows:—(*a*) unmanured and maintained at 60 per cent. saturation with water; (*b*) green manured with leaves of *Pongamia glabra* at 100 g. per pot and maintained at 60 per cent. saturation; (*c*) unmanured and swamped to a depth of 3 inches; and (*d*) green manured as in (*b*) followed by swamping as in (*c*). The green manure was applied by cutting the leaves into small bits which were mixed thoroughly with the soil to a depth of 6 inches. All the pots were maintained under field conditions with adequate provision for drainage.

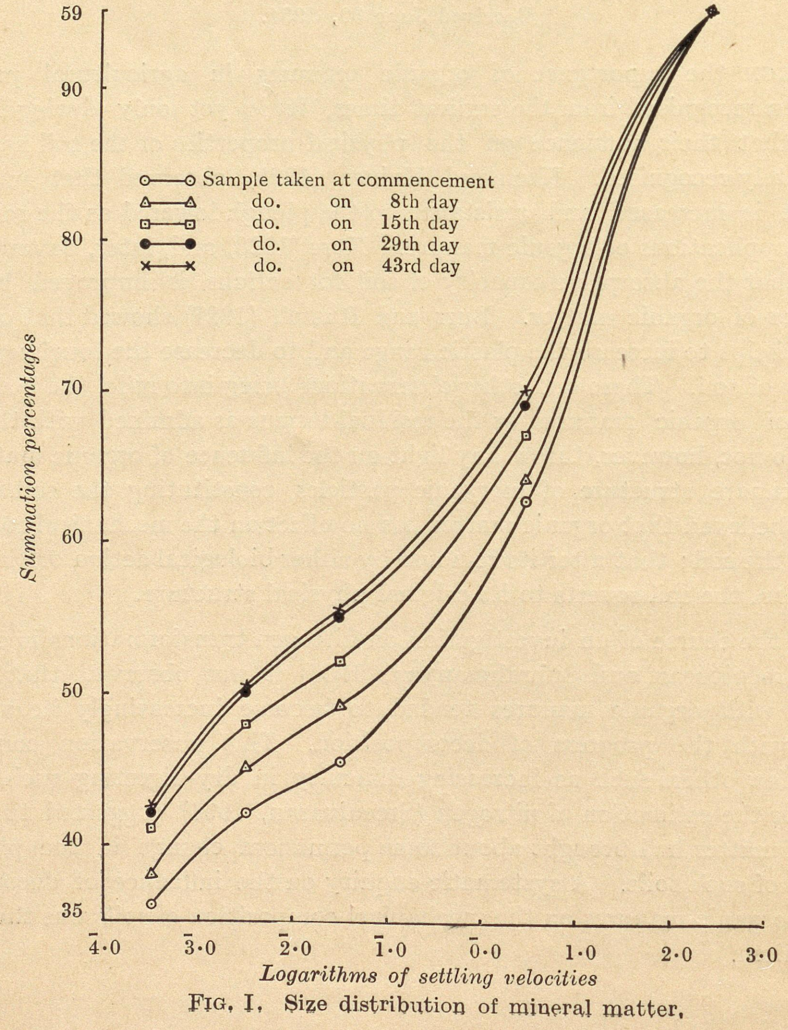

FIG. I. Size distribution of mineral matter.

TABLE I.

Treatment	Fraction	Percentages on Air-Dry Basis														
		0 – 3 inches						3 – 6 inches					6 – 9 inches			
		Time in days						Time in days					Time in days			
		8	15	29	43	57	71	8	15	29	43	71	8	15	29	43
Green manure—60 per cent. sat. ..	Coarse	46·6	44·9	42·8	41·8	41·7	42·0	47·8	..	48·9	44·8	44·8	48·9	46·1	45·9	45·8
	Fine	47·5	50·0	50·3	51·1	52·5	50·4	45·2	48·3	49·1	49·6	49·2	45·2	46·4	45·1	48·5
Green manure—swamped	Coarse	45·3	42·0	40·5	39·0	40·0	39·6	45·8	46·3	45·0	44·3	44·3	48·4	46·0	45·2	45·4
	Fine	49·4	53·0	55·4	56·0	56·2	55·4	47·4	51·1	51·8	51·6	49·7	45·8	46·3	47·8	48·4
Unmanured—60 per cent. sat. ..	Coarse	48·9	46·4	46·0	45·0	43·7	45·1	47·9	..	47·3	45·6	45·5	49·2	47·4	46·6	46·5
	Fine	46·0	47·3	48·2	48·7	48·7	48·0	46·6	..	45·7	47·5	47·7	44·6	46·1	46·7	46·3
Unmanured—swamped	Coarse	48·2	..	45·1	45·0	43·4	45·3	47·4	47·1	46·5	46·4	45·8	49·2	46·8	46·5	45·5
	Fine	46·1	47·2	47·9	48·5	50·4	47·7	46·6	46·0	47·1	48·0	48·5	46·0	46·8	46·7	47·6

At start: 0—3″, 3—6″ or 6—9″ — Coarse fraction = 50·2; Fine fraction = 46·2.

At stated intervals, the contents of whole pots were separated into three-inch layers and the mechanical composition of the soil in each layer determined according to the International Method (A.E.A. Sub-Committee, 1926) after destroying organic matter by boiling with 6 per cent. hydrogen peroxide. The results were grouped together under two main heads, (1) coarse fraction including coarse and fine sand, and (2) fine fraction representing silt and clay (including solution losses).

It may be seen from the figures (Table I) that in none of the cases was there any perceptible effect on the composition of the soil below the first three inches. The surface layers of the unmanured specimens were not also appreciably altered. On the other hand, the green manured soils showed a significant change with the progress of the decomposition of organic matter. This was particularly so in the case of the water-logged specimens in which the coarse fraction showed a distinct fall while the fine fraction showed a corresponding rise.

The summation curve for the surface layer of the green manured and swamped soil at the different intervals was drawn according to Robinson (1924). The figure (I) showed that there was a gradual change in the particle size distribution of the soil during the first 29 days after which it was not appreciable.

Effect of preliminary treatment with hydrochloric acid.—With a view to determining whether the small quantities of hydrochloric acid added to the soil suspension prior to dispersion were in any way responsible for the changes observed in the case of specimens treated with green manure, some experiments were carried out determining the mechanical composition with and without that acid. The following were the results obtained for the samples (0–3″) collected on the 57th day (Table II).

TABLE II.

Fraction	Percentages on Air-Dry Basis							
	Green manured (60 per cent. sat.)		Green manured (swamped)		Unmanured (60 per cent. sat.)		Unmanured (swamped)	
	With HCl	Without HCl	With HCl	Without HCl	With HCl	Without HCl	With HCl	Without HCl
Coarse sand ..	25·7	24·6	25·3	24·0	27·4	27·4	27·2	25·8
Fine sand	16·0	23·2	14·7	19·1	16·3	21·9	16·2	22·4
Silt + clay ..	51·9	46·6	55·7	50·6	48·7	46·5	49·9	45·0

It may be seen from the above that treatment with dilute hydrochloric acid makes comparatively small difference with regard to the percentage of coarse sand. On the other hand, the percentage of fine sand is decreased and that of clay and silt increased as the result of the treatment. This is to be observed in all the cases, irrespective of the other treatments to which the soil is subjected. It may be inferred therefore that addition of hydrochloric acid has the general effect of breaking up the mineral matter which would otherwise cement together the clay particles and thus yield coarse aggregates. Indeed, as previously observed by Hall (1904) fairly large quantities of mineral matter, especially iron, could be seen in the fine sand fraction when hydrochloric acid was not added.

Solution Losses.—The quantities of minerals, chiefly iron and aluminium, lost in solution by treatment with hydrochloric acid were determined by precipitation with ammonia and weighing after ignition (Table III).

TABLE III.

Treatment	Depth in inches	Percentages					
		Time in days					
		8	15	29	43	57	71
Green manured— 60 per cent. sat.	0—3	0·61	0·68	0·68	0·55	0·58	0·50
	3—6	0·62	0·64	0·63	0·55	..	0·49
	6—9	0·61	0·61	..	0·58	..	..
Green manured— swamped	0—3	0·66	0·92	0·73	0·60	0·51	0·52
	3—6	0·63	0·66	0·63	0·56	..	0·54
	6—9	0·53	0·60	0·71	0·52	..	..
Unmanured— 60 per cent. sat.	0—3	0·50	0·64	0·60	0·60	..	0·54
	3—6	0·61	0·56	0·53	0·52	..	0·54
	6—9	0·55	0·60	..	..	..	..
Unmanured— swamped	0—3	0·56	0·61	0·55	0·59	0·52	0·51
	3—6	0·56	0·62	0·55	0·52	..	0·53
	6—9	0·60	0·57	..	0·50	..	..

Loss in solution at the commencement in all the cases = 0·60 per cent.

The quantities passing into solution were comparatively small and except in a few cases, not significantly different from each other. There was distinct increase in the quantity of minerals dissolved from the green manured and swamped specimens between the 8th and the 29th days, but subsequently they tended to diminish and were not appreciably different from the others.

Soil structure and capacity for moisture retention.—The samples of soil collected at different stages were dried at 100°C. for 3 to 4 hours. The percentages of moisture as determined on air-dry material are given in Table IV.

TABLE IV.

Treatment	Depth in inches	Time in days					
		8	15	29	43	57	71
Green manured— 60 per cent. sat.	0—3	2·1	2·4	2·3	2·2	2·2	2·3
	3—6	1·9	2·0	2·1	2·0	..	2·1
	6—9	1·6	1·7	2·0	1·9	..	..
Green manured— swamped	0—3	2·9	2·5	2·5	2·4	2·4	2·4
	3—6	1·9	2·0	2·0	2·5	..	2·1
	6—9	1·7	1·7	1·8	1·8	..	..
Unmanured— 60 per cent. sat.	0—3	1·6	..	1·7	..	1·7	1·6
	3—6	1·6	..	1·6	..	..	1·6
	6—9	1·5	..	1·8	..	..	..
Unmanured— swamped	0—3	1·7	..	1·8	..	1·8	1·8
	3—6	1·7	..	1·9	..	..	1·7
	6—9	1·6	..	1·8	..	..	..

Moisture content at the commencement in all the cases = 1.7 per cent.

A comparison with Table I would show that the change in soil structure has no influence on moisture-retaining capacity. The latter would appear to be largely determined by the quantity of organic matter present. Thus, the green manured specimens have all got higher moisture contents than the unmanured ones. Swamping, by itself, appears to have little effect on the moisture-retaining capacity of the soil.

Silica-sesquioxide ratio.—The importance of this determination has been stressed by a number of workers (Robinson and Holmes, 1924; Joseph and Hancock, 1924; Anderson and Mattson, 1926; Mattson, 1926; Robinson, 1928; Holmes, 1928; Crowther, 1930; and Baver and Scarseth, 1931). With a view to ascertaining whether the change in the physical texture of the soil was accompanied by some alteration in the silica-sesquioxide ratio, the clay and silt fractions of the surface layers (0 – 3″) of the green manured and swamped specimens were analysed by fusion methods according to A.O.A.C. (1930).

TABLE V.

Time in days	Percentages		$\frac{SiO_2}{R_2O_3}$
	SiO_2	R_2O_3	
0	36·5	54·0	0·68
8	36·0	51·0	0·71
15	38·7	52·9	0·73
29	39·8	55·3	0·72
43	40·0	55·1	0·73
57	41·5	55·3	0·75
71	42·1	57·3	0·74

With the progress of the decomposition, there was a definite tendency for the percentages of both silica and the sesquioxides to rise (Table V). From 90·5 per cent. of the total they had risen, in the course of 71 days, to 99·3 per cent. thereby showing that the surface layer consisted almost exclusively of the oxides of iron, aluminium and silicon. This would suggest that potassium, calcium and other cations which were originally associated with the fine fractions had been steadily removed and their place taken by the three oxides. It would thus be seen that the green manure had brought about a change not only in the sizes but also in the chemical nature of the mineral particles constituting the finer fractions of the soil. The silica-sesquioxide ratio had also changed, though not to any considerable extent. The observations would suggest that the silica content increased at a slightly faster rate than that of the sesquioxides.

Discussion.

The results of the present enquiry are of much scientific as well as practical interest. In addition to showing how the physical properties of the soil may be altered by the decomposition of organic matter, they also indicate how, under the conditions of the swamp soil, the general fertility may also be affected.

Although, the unmanured specimens, as also those maintained at 60 per cent. saturation, showed very little change in their mechanical composition, the observations in the case of the manured and swamped ones would suggest that, under such conditions, the soil would tend to become richer in the fine fractions and heavier in general behaviour. Each season of manuring followed by swamping may lead to further reduction in the coarse fractions accompanied by corresponding rise in the fine ones, so that the soil becomes increasingly heavy in character. Cultivation operations would also help in this process by exposing fresh layers of the soil to conditions which would alter its structure. In this manner, a considerable part of the first few feet of the soil which are of agricultural interest may eventually be modified in composition and character. Similar changes may also occur in dry cultivated soils in regions of high rainfall or areas which are subject to frequent inundations. Profuse irrigation unattended by proper drainage may also lead to similar results.

The mechanical composition of the soil, especially under conditions of wet cultivation, is partly determined by the nature of the inorganic materials present suspended in the water used for irrigation. It is a matter of common experience, especially in the deltaic districts of India, that, depending on the situation of the land, considerable amounts of fine sand, silt or even clay are deposited at the surface of the soil. The effect of the decomposition of organic matter will therefore be modified, to some extent, by the fresh materials thus added to the soil from year to year. The reverse may also sometimes happen, especially on hill slopes. The fine fractions may be washed away by the rains exposing only the coarse ones at the surface. In this manner, the effect of decomposition of organic matter may be modified and, in some cases, even nullified by the situation of the land, the system of irrigation, climatic conditions and such like.

The changes in chemical composition are even more important than alterations in physical texture. At the commencement of the experiment, the fine fractions of the soil contained about 9 per cent. of inorganic constituents including potassium, calcium, phosphates and other fertilizing ingredients. After about 71 days of swamping, in presence of green manure, the proportions of those constituents is reduced to under 1 per cent. and their place taken by the oxides of silicon, iron and aluminium.

Further work is needed to throw light on the mechanism of the processes which led to the changes in the physical texture of the soil and chemical composition of the fine fractions. It may, nevertheless, be indicated that the decomposition of organic matter results in the production of different acids (Subrahmanyan, 1929) which attack the coarse fractions of the soil bringing different minerals into solution (W. O. Robinson, 1930). Some of the minerals such as iron and aluminium re-precipitate after a time while others like calcium and potassium continue to remain in solution (Sundara Iyengar, private communication). The position with regard to silica is not so clear, but there is evidence to show that it is also brought into solution (Venkataramanan, unpublished data) under the conditions of the swamp soil and subsequently reprecipitated. As the result of these changes, the fine fractions gain in iron, aluminium and silicon while certain other constituents are lost. It is hoped that the results of these and related enquiries would form the subject of later communications.

Summary.

1. As the result of decomposition of green manure in a swamp soil, the coarse fractions (including coarse and fine sand) of the surface layer (first 3 inches) decreased by 11·2 per cent. while the fine ones (silt + clay) increased by 9·8 per cent. in the course of 43 days. The effect was less pronounced in the manured soil maintained at 60 per cent. saturation, while no alteration was to be noticed in the case of the unmanured specimens.

2. Treatment with dilute hydrochloric acid prior to dispersion had no appreciable effect on the estimates of mechanical composition obtained in the different cases. Loss in solution was also comparatively small.

3. The silica-sesquioxide ratio increased slightly as the result of decomposition of green manure in swamp soil. The composition of the fine fractions was also altered, the total percentages of the oxides of iron, aluminium and silicon increasing from 90·5 to 99·3 in the course of 71 days.

4. The practical significance of the above and related observations has been discussed.

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