STUDIES ON SOIL ORGANIC MATTER

PART III. THE EXTRACTION OF ORGANIC CARBON AND NITROGEN FROM SOIL

By J. M. BREMNER, *Rothamsted Experimental Station, Harpenden, Herts*

(With Two Text-figures)

The second paper in this series (Bremner & Lees, 1949) gave the results obtained in a survey of the abilities of various neutral reagents to extract organic matter from soil. In that survey the nitrogen content of an extract was taken as an index of its organic matter content because no reliable method was available for the determination of small amounts of organic carbon in soil extracts. Moreover, this permitted some comparison of the extracting powers of organic and inorganic reagents. It was later found (Bremner, 1949*a*) that the organic carbon contents of soil extracts could be determined accurately by the wet combustion method of Van Slyke & Folch (1940). This made it possible to test the reliability of the index used in the previous work and to study the relation of carbon to nitrogen in soil extracts. The results of these investigations are given below.

EXPERIMENTAL

The soils employed have already been described (Bremner, 1949*b*; Bremner & Lees, 1949). Before use they were leached with cold 0·1 N-hydrochloric acid to remove inorganic nitrogen, carbonates and exchangeable bases and then washed thoroughly with distilled water; the acid-leached Burwell soil was washed with M-KCl to prevent dispersion of organic matter. The acid-leached soils were air-dried at room temperature and ground to pass through a 1 mm. sieve.

Nitrogen was determined by the micro-Kjeldahl method previously described (Bremner, 1949*b*) and carbon by the method of Van Slyke & Folch (1940).

RESULTS

Table 1 gives the amounts of organic carbon and nitrogen extracted from the acid-leached soils by various inorganic reagents; the C/N ratios of the extracts are given for comparison. The amounts of organic carbon and nitrogen extracted from Burwell soil by the same reagents when the preliminary acid-leaching was omitted are shown in Table 2. The rates of extraction of organic carbon and nitrogen from acid-leached samples of Broadbalk and Burwell soils by pyrophosphate and alkali are shown in Figs. 1 and 2. The C/N ratios of pyrophosphate, fluoride, carbonate and alkali extracts of acid-leached Burwell soil and of the humic (acid-insoluble) fractions of these extracts are compared in Table 3. The humic fractions were obtained by acidifying the extracts with dilute sulphuric acid to pH below 2. The precipitates were removed by centrifugation, washed thoroughly with M-KCl, and redissolved in neutral 0·1 M-sodium pyrophosphate. Aliquots were then taken for carbon and nitrogen determinations.

Table 1. *Extraction of organic carbon and nitrogen from acid-leached soils by inorganic reagents*

Time of extraction, 24 hr.

Extractant	N extracted (% total soil N)				C extracted (% total soil C)				C/N ratio of extract			
	A	B	C	D	A	B	C	D	A	B	C	D
0·1 M-sodium pyrophosphate (pH 7·0)	10·6	11·1	9·3	25·0	12·5	11·1	7·7	37·7	10·7	10·3	12·7	22·4
0·5 M-sodium fluoride (pH 7·0)	9·2	6·4	6·3	22·8	10·7	6·3	4·7	33·5	10·6	10·1	11·3	21·8
0·5 M-sodium carbonate (pH 10·6)	10·9	10·6	8·6	27·4	12·5	10·4	5·8	35·0	10·4	10·0	10·3	19·0
0·5 M-sodium hydroxide	35·2	40·0	33·8	62·3	34·8	34·4	20·9	67·4	9·0	8·8	9·4	16·0

Soil	C content of acid-leached soil (%)	N content of acid-leached soil (%)	C/N ratio of acid-leached soil	ml. extractant/g. of soil
A Hoosfield	0·86	0·095	9·1	5
B Broadbalk	2·48	0·241	10·3	5
C Allotment	7·52	0·492	15·3	5
D Burwell	48·8	3·3	14·8	75

DISCUSSION

The results given in Table 1 show that:

(1) There is no constant relation between the C/N ratio of a soil and the C/N ratios of extracts of that soil. In some cases the ratio is greater in the soil than in the extracts, in others smaller.

(2) Alkali extracts more nitrogen in relation to carbon from soil than do neutral or mildly alkaline reagents.

(3) There is a wide variation in the C/N ratios of extracts obtained by treating different soils with the same reagent.

(4) There is some variation in the C/N ratios of extracts obtained by treating the same soil with different reagents. This variation is greatest with highly organic soils.

Table 2 shows that the C/N ratio of a neutral 0·1 M-sodium pyrophosphate extract of the highly organic Burwell fen soil was almost twice that of an 0·5 M-sodium hydroxide extract of the same soil.

Table 2. *Extraction of organic carbon and nitrogen from Burwell soil by inorganic reagents*

10 ml. extractant/g. of soil. Time of extraction, 24 hr.

Extractant	N extracted (% total soil N)	C extracted (% total soil C)	C/N ratio of extract
0·1 M-sodium pyrophosphate (pH 7·0)	22·0	34·4	22·7
0·5 M-sodium fluoride (pH 7·0)	21·9	32·4	21·5
0·5 M-sodium carbonate (pH 10·6)	25·5	34·8	19·8
0·5 M-sodium hydroxide	24·9	19·9	11·6

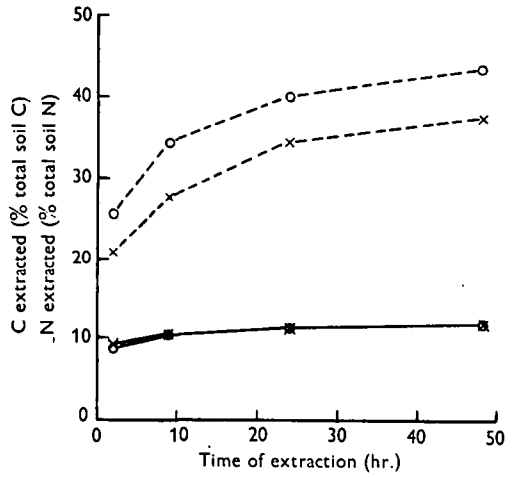

Fig. 1. Variation with time of the amounts of organic carbon and nitrogen extracted from acid-leached Broadbalk soil by alkali and pyrophosphate. 5 ml. extractant/g. of soil. --○--, N extracted by 0·5 M-NaOH; --×--, C extracted by 0·5 M-NaOH; —○—, N extracted by 0·1 M-sodium pyrophosphate (pH 7·0); —×—, C extracted by 0·1 M-sodium pyrophosphate (pH 7·0).

Similar results were obtained with other highly organic soils. For example, the C/N ratios of 0·5 M-sodium hydroxide and 0·1 M-sodium pyrophosphate (pH 7·0) extracts of Swaffham fen soil were 12·1 and 24·2 respectively. These results show that, with highly organic soils, the nitrogen-extracting power of an extractant cannot be taken as an index of its ability to extract organic carbon. With mineral soils, however, the index is fairly reliable, and its use in comparative work such as that described in the previous paper (Bremner & Lees, 1949) would appear to be justifiable.

The effect of acid-leaching on extraction of organic carbon and nitrogen from the highly calcareous Burwell soil can be seen by comparing the results given in Table 2 with the corresponding figures in Table 1. Although acid-leaching has little effect on extraction by sodium pyrophosphate, fluoride or carbonate, it has a very important effect on extraction by sodium hydroxide.

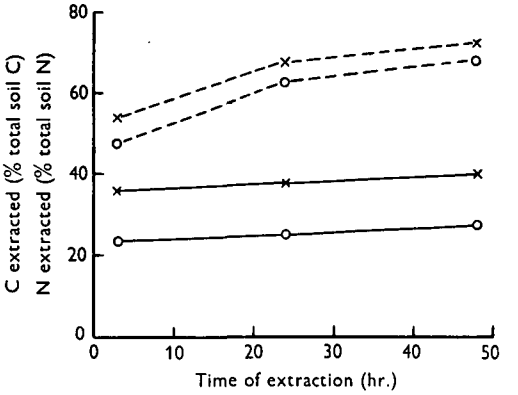

Fig. 2. Variation with time of the amounts of organic carbon and nitrogen extracted from acid-leached Burwell soil by alkali and pyrophosphate. 75 ml. extractant/g. of soil. --○--, N extracted by 0·5 M-NaOH; --×--, C extracted by 0·5 M-NaOH; —○—, N extracted by 0·1 M-sodium pyrophosphate, (pH 7·0); —×—, C extracted by 0·1 M-sodium pyrophosphate (pH 7·0).

Table 3. *The* C/N *ratios of the humic fractions of extracts of acid-leached Burwell soil*

Extractant	C/N ratio of extract	C/N ratio of humic fraction of extract
0·1 M-sodium pyrophosphate (pH 7·0)	22·4	22·2
0·5 M-sodium fluoride (pH 7·0)	21·8	21·0
0·5 M-sodium carbonate (pH 10·6)	19·0	19·9
0·5 M-sodium hydroxide	16·0	16·7

There is a striking similarity between the influence of time on the extraction of organic carbon from soil by pyrophosphate or alkali and its effect on the extraction of organic nitrogen from the same soil by the same reagent (Figs. 1, 2). Similar results were obtained when 0·5 M-sodium fluoride (pH 7·0) and 0·5 M-sodium carbonate (pH 10·6) were used for extraction. The fact that, throughout the course of continued extraction by any one reagent, the organic carbon is dissolved only along with, and in proportion to, the organic nitrogen, shows that the

organic carbon and nitrogen of soil are intimately associated. Hobson & Page (1932) also found that the alkali extraction of organic carbon from soils followed a closely similar course to the alkali extraction of organic nitrogen from the same soils.

It is clear from Figs. 1 and 2 that although time has little effect on the extraction of organic carbon and nitrogen from soil by neutral pyrophosphate it has an important effect on extraction by alkali. The marked effect of time on extraction of nitrogen from soil by alkali was noted in the previous paper (Bremner & Lees, 1949). A possible explanation of these results is that, in the presence of alkali, a slow depolymerization of the organic complexes of soil takes place with the formation of products that are soluble in alkali.

There is little difference between the C/N ratio of a soil extract and the C/N ratio of its humic fraction; both depend upon the reagent used for extraction (Table 3).

It may be pointed out here that the colour of a soil extract cannot be taken as an index of its organic matter content. A neutral 0·1 M-sodium pyrophosphate extract of Hoosfield soil was much darker in colour than an 0·5 M-sodium hydroxide extract of the same soil although the alkali extract contained almost twice as much organic matter as the pyrophosphate extract.

SUMMARY

A study has been made of the extraction of organic carbon and nitrogen from soil by various inorganic reagents. The results show that the organic carbon and nitrogen of soil are so intimately associated that, under the influence of any one of the reagents tested, the organic carbon is dissolved only along with, and in proportion to, the organic nitrogen. The relative proportions of carbon and nitrogen extracted vary, however, with both the soil and the extractant.

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