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HUMATES AND SOIL FERTILITY.

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PREVIOUS to the time of Liebig it was quite generally supposed that plants derive their food principally from the humus of the soil, but after Liebig showed that the greater part of plant food was derived from the atmosphere, humus received less attention at the hands of chemists and other investigators, possibly less than it deserved. Agriculturists, however, have assigned a high place to humus in the soil, recognizing that it played an important part in modifying the physical conditions of the soil, in relation of soils to the water content as well as to the soil temperature. Chemists gave so little attention to this that in soil analyses humus has not been generally estimated, and almost no determinations have been made of the relation of humus to the mineral matter, or in other words the amounts and kinds of mineral constituents contained in the humates, or whether any relation existed between the amount of phosphates, potash, lime, and nitrogen contained in the soil humates and the productivity of the soil. We do not even know what humus is except that it is a very complex product. It would seem that a product so highly prized by the farmer as a constituent of his soil, should be worthy of most careful study. Snyder has given considerable attention to the subject of humus in the soil and humus products. In this article an attempt will be made to trace a relationship between the humates and soil fertility, and to show the necessity for a fuller consideration of the humates by the soil analyst. Although my own observations and experiments have extended over a period of eight years and many determinations have been made at different dates during this time, as other duties have permitted, work in this field has only just reached the point of showing where work must begin without having accomplished anything definite more than a strong conviction of the necessity for a most careful and painstaking investigation of the humus question, especially in any investigation of the soils of North Dakota.

If by placing on record at this time the data secured during the past few months other workers are interested in soils and induced to take up the work, I shall have accomplished my object. The study of data presented by different workers will enable us to determine what are general principles and what results peculiar to local conditions. The soils of North Dakota contain such quantities of humus and organic matter that many problems can only be studied on soils from other places in order to determine some of the most important facts in connection with the humus problem.

In the following table are given results for twenty-four samples of soils, showing the per cent. of humates and humus, also the per cent. of total phosphates, lime, potash, and nitrogen contained in the soil, together with the amounts extracted as humates.

			Nitrogen.		Phosphoric acid, P_2O_5.		Lime, CaO.		Potash, K_2O.	
Soil.	Humates.	Humus.	Total.	In humus.	Total.	In humus.	Total.	In humus.	Total.	In humus.
411	6.85	4.03	0.340	0.163	0.29	0.086	0.58	0.336	0.32	0.110
413	9.20	4.45	0.390	0.193	0.37	0.168	0.37	0.263	0.51	0.201
414	5.92	2.54	0.190	0.152	0.16	0.097	0.40	0.210	0.21	0.083
415	8.02	3.94	0.200	0.140	0.30	lost	0.80	lost	0.30	lost
416	8.86	3.66	0.300	0.146	0.26	0.184	2.48	0.680	0.18	0.089
417	5.37	3.20	0.310	0.152	0.29	0.116	0.94	0.453	0.19	0.136
419	7.42	4.06	0.345	0.105	0.27	0.161	2.70	0.159	0.42	0.139
420	3.84	1.56	0.187	0.041	0.37	0.179	2.10	0.892	0.22	0.075
421	4.27	2.53	0.234	0.094	0.31	0.192	2.00	1.030	0.18	0.089
422	5.79	4.10	0.218	0.111	0.27	0.199	1.25	1.010	0.45	....
423	15.26	7.73	0.390	0.176	0.33	0.132	0.83	0.370	0.44	0.200
424	14.57	7.25	0.250	0.152	0.38	0.184	0.80	0.420	0.60	0.204
425	14.81	7.90	0.300	0.176	0.40	0.143	0.86	0.343	0.73	0.200
426	14.20	7.86	0.396	0.175	0.38	0.117	1.01	0.476	0.54	0.200
427	14.65	7.01	0.300	0.133	0.39	0.139	0.85	0.429	0.63	0.233
428	14.81	6.92	0.456	0.183	0.39	0.161	1.05	0.389	0.50	0.180
270*a*	7.40	4.78	0.220	0.157	0.14	0.110	trace	0	0.44	....
270*b*	7.32	4.18	0.310	0.256	0.24	0.137	0.64	0.423	0.25	....
86*a*	7.57	4.21	0.250	0.169	0.18	0.120	0.47	0.209	0.55	....
86*b*	5.85	3.33	0.180	0.123	0.20	0.103	0.34	0.170	0.35	....
277*a*	9.99	6.43	0.360	0.284	0.16	0.092	0.33	0.186	0.23	....
277*b*	11.10	4.89	0.450	0.362	trace	trace	1.12	0.609	0.42	....
81*a*	7.65	4.20	0.250	0.170	0.18	0.117	0.91	0.513	0.59	....
81*b*	8.94	3.80	0.180	0.115	0.20	0.225 ?	0.79	0.453	0.58	....

The soils examined were from various parts of the state, mostly outside of the valley, excepting 423 to 428 inclusive, which were from the agricultural college farm, and represent principally soils from the plots where crop rotation experiments are being conducted. It will be seen that there is quite a range of variation for the different constituents in the twenty-four samples. This variation may best be shown in tabular form.

In twenty-four samples.	Humus.	Humates.	Nitrogen. Total.	Nitrogen. In humus.	Phosphoric acid, P_2O_5. Total.	Phosphoric acid, P_2O_5. In humus.	Lime, CaO. Total.	Lime, CaO. In humus.	Potash, K_2O. Total.	Potash, K_2O. In humus.
Minimum.	3.84	1.56	0.180	0.041	trace	0.086	trace	0	0.18	0.075
Maximum	15.26	7.90	0.456	0.362	0.40	0.199	2.70	1.03	0.73	0.233
Average ..	9.15	4.77	0.292	0.163	0.269	0.138	0.944	0.436	0.409	0.153

Phosphoric acid for 81*b* has been excluded, as evidently there is an error in one of the sets of determinations, although good duplicates are shown for each set. From this table it is evident that there is quite a range of mineral matter in the humates, and that a varying proportion of these constituents exist in the humates as compared with the total in the soil. The next table shows the per cent. of these several constituents that existed in the humates as compared with the total in the soil.

PER CENT. OF THE TOTAL IN THE HUMATES.

Number.	Nitrogen.	Phosphate, P_2O_5.	Lime, CaO.	Potash, K_2O.	Humus.
411	47.9	29.7	57.9	34.3	58.9
413	49.5	45.4	71.1	39.4	48.3
414	80.0	60.6	52.5	39.5	42.9
415	70.0	...	...	...	49.1
416	48.6	70.7	27.4	49.4	41.3
417	49.0	40.0	48.0	71.6	59.5
419	30.4	59.6	5.88	33.1	54.7
420	21.9	45.9	42.4	34.1	40.6
421	40.1	61.9	51.5	49.4	59.2
422	50.9	73.6	80.8	...	70.8
423	45.1	40.0	44.6	45.4	51.3
424	60.8	48.4	52.5	34.0	49.7
425	58.6	35.7	39.8	27.4	53.4
426	44.4	30.8	47.1	37.0	55.3
427	44.3	35.6	40.4	36.9	47.8
428	40.1	41.3	37.0	36.0	46.7
270*a*	71.3	78.6	0	...	64.6
270*b*	82.5	56.9	66.1	...	57.1
86*a*	67.6	66.6	44.5	...	55.6
86*b*	68.3	51.5	50.0	...	56.9
277*a*	78.9	57.5	56.3	...	64.6
277*b*	80.4	trace	54.4	...	44.0
81*a*	68.0	65.0	56.3	...	56.2
81*b*	63.9	112(?)	57.3	...	42.5
Average	55.8	51.3	46.2	37.4	52.1

If we represent the figures given in a form to show the amounts per acre, assuming that one acre of soil to the depth of one foot weighs 2,225,000 pounds, then for nitrogen we have:

NITROGEN PER ACRE.

	Total in soil. Pounds.	In humus. Pounds.
Highest	10,146	8,054
Lowest	4,005	912
Average	6,497	3,627

In the same manner excluding the soil when there was almost an absence of phosphates, we have for phosphoric acid:

PHOSPHORIC ACID (P_2O_5) PER ACRE.

	Total in soil. Pounds.	In humus. Pounds.
Highest	8,900	4,428
Lowest	3,115	1,913
Average	5,985	3,061

Here we find marked differences, and when we come to study the character of the humus itself, we find other conditions not yet understood, and which we do not care to consider at the present time. The unqualified term *humus* conveys but little more meaning than the term soil without any specifications as to kind and properties.

INFLUENCE OF CONTINUOUS CROPPING.

A field that has been continuously cropped for seventeen years in succession, occasionally to oats, but principally to wheat, began to show a marked decrease in yield. The soil is quite light, containing considerable sand, in fact it would be classed as a sandy loam. A field adjoining had never been broken, and originally the two fields were alike in general appearance, as I am informed by the proprietor. The ordinary soil analyses gave results as follows:

	Old soil. Cropped seventeen years. No. 420.	New soil. Unbroken prairie. No. 421.
Moisture	2.76	2.74
Sand, silica, etc	72.58	75.50
Soluble silica, SiO_2	11.73	9.65
Volatile matter	5.26	6.30
Potash, K_2O	0.22	0.18
Soda, Na_2O	0.42	0.66
Lime, CaO	2.10	2.00
Magnesia, MgO	0.08	0.07
Manganese, Mn_2O_3	trace	trace
Iron, Fe_2O_3	0.22	0.20
Alumina, Al_2O_3	3.41	2.19
Phosphoric acid, P_2O_5	0.37	0.31
Sulphuric acid, SO_3	0.79	0.72
Nitrogen	0.187	0.234

Until the last three or four crops the field had been a good producer, and an examination of the results above indicates very little as to the probable reason for the loss of productive power. The nitrogen is lower than the average for the state, but no lower than for the same group of soils in the state, and not nearly so low as in many fertile soils from other states. Of phosphates there is a good supply. Taking all things into consideration, I should find it difficult, if not quite impossible from the above analyses, to determine which field had been longest cropped.

An examination for the soil humus was then made with results as follows:

PER CENT.

	Old soil. No. 420.	New soil. No. 421.
Humates	3.04	4.27
Humus	1.56	2.53
Phosphoric acid, P_2O_5	0.179	0.192
In the Humates:		
Lime, CaO	0.892	1.030
Potash, K_2O	0.075	0.089
Nitrogen	0.041	0.094

The amount of humus originally in the soil was exceptionally low for a North Dakota soil, but by continuous cropping it has been reduced thirty-nine per cent., while the nitrogen of the humus has been reduced fifty-six per cent., leaving so small an amount of humus and of nitrogen in the humates that it is questionable whether the soil would supply proper food for the growing crop. We find similar conditions, but to a less marked degree in the other mineral constituents of the soil. This investigation of the humus, even with our lack of knowledge of the true nature of humus and humates, throws great light upon the character of the soil and the possible cause for a declining crop.

RELATION OF MINERAL MATTER TO HUMUS.

Does the mineral matter of the humates change with the decrease and increase of humus in the soil? The soil that we have just examined answers in part this question, but examinations made with the soils from the college farm showed in 1891 that the average humus content for the fields that had produced wheat for fifteen years was 126,000 pounds per acre, taken to a depth of one foot, while for surrounding unbroken prairie the average gave 218,000 pounds per acre, a loss by continuous cropping, burning of stubbles, etc., of 92,000 pounds, or of 42.2 per cent.

In another case where both the humus and phosphoric acid in the humates had been determined, we find:

PER CENT.

	Humus.	P_2O_5 in humates.
1891	5.35	0.079
1894	6.82	0.091
1898	7.86	0.117

For fifteen years previous to 1891 it is said the field had been cropped continuously to wheat. Beginning with 1892 a system of crop rotation has been followed, and the productivity of the field has continued to increase.

An acre of this soil then to the depth of one foot contained of humus and of phosphoric acid, P_2O_5, in the humates:

	Humus. Pounds.	P_2O_5 in humates. Pounds.
1891	119,037	1,758
1894	151,745	2,025
1898	174,885	2,603

The gain in humus from 1891 to 1898 has been 46.9 per cent., while the gain of phosphoric acid in the form of humates has been forty-eight per cent. It will be observed that the gain in phosphoric acid in the humates has been expressed as per cent. almost the same as the gains for the humus in the same period. It has also been shown by Snyder[1] that when prepared humus is added to soils it combined with the mineral matter of the soil, forming humates.

If we calculate the nitrogen to show per cent. in humus, and the other mineral constituents to per cent. in humates, we shall have other relations brought out in a way not shown by the previous tables.

TABLE SHOWING PER CENTS.

		In humates.		
Number.	Nitrogen in humus.	Phosphoric acid, P_2O_5.	Lime, CaO.	Potash, K_2O.
411	4.43	1.26	4.03	1.62
413	4.33	1.82	2.85	4.48
414	5.93	1.63	3.74	1.48
415	3.55	...	...	...
416	3.98	2.09	7.82	1.01
417	4.87	2.14	8.32	2.51
419	1.41	2.17	2.14	1.90
420	1.07	4.66	25.57	1.98
421	2.20	4.49	24.12	2.08
422	1.91	3.43	17.44	...
423	2.26	0.87	2.42	1.36
424	2.13	1.26	2.94	1.37
425	2.22	0.96	2.31	1.35
426	2.23	0.83	3.35	1.40
427	1.90	0.92	3.01	1.60
428	2.65	1.08	2.65	1.20
270*a*	3.30	1.48	0	....
270*b*	6.01	1.87	5.79	....
86*a*	4.02	1.56	2.74	....
86*b*	3.68	1.80	2.90	....
277*a*	4.42	0.94	1.81	....
277*b*	7.40	trace	5.39	....
81*a*	4.00	1.54	5.71	....
81*b*	3.03	2.05	5.07	....

Other experiments are now in progress to answer some of the many questions that have been suggested by the foregoing.

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[1] This Journal, 19, 738.