4. SOIL ORGANIC MATTER AND MANURIAL TREATMENTS[1]

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Chemical and biological studies of the residual effects on the soil of various manurial treatments are essential to the proper interpretation of field data with respect to the differences in response of field crops to fertilizer applications. In our more comprehensive field plat experiments, therefore, provisions are made for such studies, especially as related to the effects of the particular treatments on soil organic matter. A review of the literature concerning such studies shows that as the result of different conditions and methods of experimentation the investigators differ widely in their interpretations and subsequent recommendations. This is especially true in regard to the comparative effects of different liming materials on the decomposition of soil organic matter.

A brief review of the literature on this one phase of the subject under consideration serves to emphasize the different results secured.

In their studies on Rhode Island soils in 1899 Wheeler, Sargent, and Hartwell (18)[3] concluded that air-slaked lime caused an increase in organic matter on grass plats as compared to unlimed soils.

Hess (6) in 1899 and 1900 studied the limed plats of the Pennsylvania field experiments and found less organic matter and nitrogen on the plats treated with caustic lime than on those that had received carbonate of lime.

Hartwell and Kellogg (5) in 1906 concluded from further studies at the Rhode Island Station that the effect of lime depended largely on soil reaction.

Mooers, Hampton, and Hunter (12) in 1912 reported a greater loss of nitrogen on limed plats than on those unlimed.

McIntire (11) from a study of the Pennsylvania plats in 1911 concluded that caustic lime caused a decrease in organic matter as compared to carbonate of lime.

Lipman and Blair (8) in 1913 reported a greater loss of nitrogen on limed land than on unlimed soil.

Potter and Snyder (13) reported in 1916 a gain of nitrogen as the result of liming.

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[3]Reference by number is to "Literature Cited," p. 395.

Bear (2) in his studies of Dekalb soil at the West Virginia Experiment Station in 1916 concluded that quick lime caused a loss of organic carbon and nitrogen.

In 1922, Carlson (3) from his studies concluded that in general the limed plats contained more organic carbon and nitrogen than did the unlimed plats.

Hess (6) in his studies of the Pennsylvania plats in 1899 found in the limestone treated soil 0.2% organic carbon and 0.0169% nitrogen in excess of that present in the soil treated with caustic lime. Hopkins (7) from these data computed that the effect of caustic lime as compared with limestone was equivalent to the destruction (in terms of the nitrogen difference of less than 0.02%) of 37½ tons of farm manure in 16 years, or equivalent to the liberation of more than $7.00 worth of nitrogen for every ton of caustic lime applied. In like manner the difference of 0.2% of organic carbon was computed to the equivalent loss of 37.6 tons of fresh manure in 16 years.

It is of interest to note that in computing the difference of 0.0169% nitrogen to the equivalent of pounds per acre Hopkins used as his weight per acre 9 inches of soil, 2,224,800 pounds as suggested by Hess. However, the carbon figures were computed on the basis of 2,700,000 pounds per acre.

In 1921, the writer (19) made a detailed study of the same plats as those examined by Hess and McIntire. As a result of this later study it was concluded:

(A) The odds, as determined by Student's method as discussed by Love and Brunson (10) and Love (9), indicate that the limestone and caustic lime treated plats are not significantly different in their content of organic carbon and nitrogen at the end of 40 years of continuous treatment.

(B) When the limed plats are compared with the untreated check plats in content of organic carbon, the caustic lime treatment only seems significantly higher than the untreated soil.

(C) In nitrogen content both the caustic lime and limestone treated soils are significantly higher than the untreated soil.

(D) The excess of organic carbon and nitrogen found on the limestone treated soil as reported by Hess and McIntire was shown to have been derived from charcoal discovered on the limestone plat of tier 4.

From a detailed study of the manure and lime and manure plats after 40 years of continuous treatment, the writer (20) concluded as follows:

(A) Lime has caused the decomposition in 40 years of 90% of the manure applied as compared to 84% where manure was used alone.

(B) It is estimated that 93% of the organic matter of the lime and manure plat is derived from crop residue compared to 88% where manure was used without lime.

(C) The lime and manure treatment showed a gain of 508 pounds per acre of nitrogen in excess of the untreated check soil compared to 214 pounds where manure was used without lime, resulting in a gain of 294 pounds in favor of the limed land.

(D) Lime has caused the decomposition of 2,900 pounds of organic matter in excess of the manure treatment, resulting in sufficient increased yields (13,120 pounds dry matter) of crops to leave a balance of 1,345 pounds of residual organic matter and 178 pounds of nitrogen.

(E) The excess of organic matter found on the unlimed manured soil as the result of earlier studies was due to the presence of charcoal discovered by the writer on plat 16, tier 2. On this plat it is estimated that 25% of the organic carbon is derived from charcoal residues.

In general, we may conclude that when used in connection with manure or a balanced mineral fertilizer the increased yields attending a normal lime application will furnish sufficient crop residue organic matter (roots and stubbles) at least to balance that lost as the result of increased bacterial activity and that there is no significant difference between the action of burnt lime and lime carbonate when applied in equivalent amounts of CaO.

COMPARATIVE RESIDUAL EFFECTS OF MANURE AND MINERAL FERTILIZERS

Independent of the nature of the fertilizing material used the ultimate residual organic matter content of a soil depends largely upon the cropping system. It is a well-known fact that soils in permanent grass invariably contain a higher proportion of organic matter and nitrogen than the same soil in a system of cultivation. Advantage of this fact is taken in the manner of planning grain rotations to alternate the periods of cultivation with a period in grass and leguminous crops. During this rest period there is a pronounced recuperative effect which under proper fertilization tends to balance the organic matter and nitrogen rapidly lost during the period of cultivation.

Snyder (16) has shown that continuous growth of wheat for eight years resulted in the loss of over 21% of the total nitrogen of the soil,

equivalent to an annual loss of 175 pounds per acre in excess of that used as plant food. Shutt (14), Alway (1), Swanson (17), and others show similar results in relation to their field studies.

At the Pennsylvania Experiment Station[4] the division strips which divide the old fertilizer plats have been in continuous bluegrass since 1867. In 1922, the writer (21) made a study of the organic matter and nitrogen content of certain of these grass strips and at the same time made a similar study of the adjoining cultivated plats. It was found that after 55 years under the two systems the grass land soils contained, as an average, 16,299 pounds per acre of organic matter and 818 pounds nitrogen in excess of the six cultivated soils. Even where 6 tons of manure and lime had been used biennially for 40 years the untreated grass land soil contained 12,265 pounds of organic matter and 600 pounds nitrogen in excess of the cultivated soil. A comparison of the untreated cultivated check soil with that of the grass strips showed a gain for the latter of 20,168 pounds per acre of organic matter and 1,160 pounds nitrogen, or a percentage increase of 36.3 in organic matter and 46.9 in nitrogen content.

In the more depleted eastern soils the problem of soil rejuvenation through the systematic use of manure and mineral fertilizers in connection with different grain rotations has been the subject of careful investigation. In these experiments it has been found that the ultimate organic matter and nitrogen content of the soil reaches a more or less definite level in a particular soil in accordance with the nature of the cropping system. Attempts to increase and maintain an abnormally high organic matter content through the excessive applications of farm manure has met with failure and resulted in excessive loss of organic carbon and nitrogen.

Bear (2) concluded from his studies of Dekalb soil at the West Virginia Experiment Station that the organic matter of a depleted soil can be increased and maintained in a rotation system through the systematic use of mineral fertilizers without the return of crop residues other than the roots and stubbles. Also, that the nitrogen content of the soil in like manner can be increased and maintained without the use of mineral nitrogen or farm manure.

In 1924, the writer (21) made a study of the residual effects of mineral fertilizers on Dekalb soil at the Snow Shoe experiment fields, including plats in a four-year grain rotation and those similarly fertilized in permanent Kentucky bluegrass pasture. At the end of

[4]These old plats were originally laid out in 1867 and from that time until 1881 were used for miscellaneous experiments. Since 1881 a definite field experiment has been conducted.

eight years of cropping it was found, as an average, that where mineral fertilizers were used the organic matter content of the soil in permanent bluegrass had increased 32.7% as compared to 18.4% in the cultivated soil. The bluegrass soil showed a gain of 33.3% in nitrogen as compared to 19.0% for the soil in grain rotation. From these data it will be seen that the rate of accumulation of organic matter under permanent bluegrass sod exceeds that of the cultivated soil by 78%.

EFFECT OF MINERAL NITROGEN ON THE ULTIMATE DECAY OF SOIL ORGANIC MATTER

When crop residues of a low nitrogen content or a wide carbon-nitrogen ratio, such as roots and stubbles, are returned to the soil, the excess of carbon is utilized by soil organisms as a source of energy. Such action continues until the ratio of nitrogen to carbon is increased approaching a more or less constant ratio of 1:12.

Sievers and Holtz (15) found that the addition of nitrogen to straw, either in the organic or inorganic form, tends to reduce the excessive loss of carbon. In this connection they make the following statement: "Under conditions where organic matter of high carbon content is plowed under, as in the case of straw and heavy cereal stubbles, a treatment with a nitrogen fertilizer before plowing will not only overcome, in large part, the depressing influence on nitrate accumulation, but will also conserve much of the organic matter contained in the residue." It is of considerable interest to determine if this significant statement of Sievers and Holtz holds true under field conditions. If so, then plat soils which have received heavy applications of mineral nitrogen where the only source of organic matter has been derived from roots and stubble should show a higher organic matter content than plats treated with mineral fertilizers without nitrogen, especially when the total yields of dry matter have been less in the second instance.

A study of the old plats at the Pennsylvania Experiment Station after 40 years of continuous cropping shows that such is not the case. In fact, the three plats treated with nitrate of soda applied biennially to the corn and wheat ground show less residual organic matter than the average of the four plats which have received acid phosphate and muriate of potash. The same is also true of the three plats treated with sulfate of ammonia. In each case the nitrogen treated plats have received the same amounts of PK. The summary in Table 1 shows the total yields and residual organic matter at the end of 40 years on untreated check plats and those that have received complete fertilizers as compared to the PK plats.

TABLE 1.—*Yields and residual organic matter after 40 years continuous cropping on Pennsylvania Experiment Station plats, average of Tiers 1 and 3.*[a]

	PK, no N	Check, no N	Nitrate of soda, pounds of N			Sulfate of ammonia, pounds of N			Dried blood, pounds of N		
			24	48	72	24	48	72	24	48	72
Yields of dry matter.....	100	63	109	113	115	102	99	91	102	109	113
Residual organic matter..	100	86	101	96	99	91	99	98	102	103	103

[a]Results expressed on basis of PK treatment as 100.

A study of Table 1 shows that nitrogen applied to the crop residues has not conserved organic matter, but, on the other hand, has apparently stimulated organic matter decay. If the total yield of dry matter produced in 40 years is divided by the pounds per acre of residual organic matter, we find that for each ton of dry matter produced on the PK plats there are left in the soil 717 pounds residual organic matter as compared to only 631 as an average for the nitrate of soda plats, 716 pounds for the sulfate of ammonia treatment, and 680 pounds on the plats treated with dried blood. From these figures it will be seen that the PK treatment shows a greater proportion of residual organic matter in relation to the total yield of dry matter.

It is of interest to study in a similar manner the effect of different amounts of nitrogen applied in ammonium salts on the conservation of soil organic matter in a system of continuous wheat culture as practiced on Broad Balk Field at Rothamsted. The summary in Table 2 shows the total yields of dry matter and residual organic matter at the end of 42 years (1852–1893) of continuous treatment as reported by Dyer (4), also the pounds per acre residual organic matter per ton of dry matter produced.

TABLE 2.—*Yields of dry matter and residual organic matter at the end of 42 years of continuous treatment on Broad Balk Field, Rothamsted.*[a]

	Mineral salts, no N	Check, no N	Full mineral and ammonium salts 43N	86N	129N
Yields dry matter.....	100	86	171	251	295
Residual organic matter[b]	100	95	109	118	122
Pounds per acre residual organic matter per ton of dry matter produced.....	100	110	64	47	41
	858 lbs.	980 lbs.	565 lbs.	416 lbs.	366 lbs.

[a]Results expressed on basis of mineral treatment (without N) as 100.

[b]Computed from the organic carbon (C x 1.724) on basis of 2,592,621 pounds soil per acre 9 inches.

A study of Table 2 shows that the addition of nitrogen has greatly increased the yields of dry matter. If it is assumed that the increased

yields have left in the soil the proportionate amounts of roots and stubble, then the effect of nitrogen has been to stimulate rather than retard organic decay. As an average, the three rates of nitrogen applications have caused an increased yield of 106% and only 17% increase in organic matter. For every ton of dry matter produced on the plat treated with minerals without nitrogen there is left in the soil 885 pounds per acre of residual organic matter as compared to only 449 pounds as an average for the nitrogen treated plats.

SUMMARY

From a brief review of the literature concerning the relation of manurial treatments to the maintenance of soil organic matter, it may be concluded that the evident differences of opinion among investigators is due to variations in methods and conditions of experimentation.

Where lime in its several forms has been used in connection with manure or a balanced mineral fertilizer, the temporary decrease in organic matter as the result of stimulated bacterial action is compensated by increased crop residues.

There is no measureable difference in the action of caustic lime and neutral carbonate on soil organic matter when applied in their equivalent neutralizing values.

Liberal use of mineral nitrogen as measured by long-time field experiments has stimulated the decay of organic matter in excess of such action by mineral fertilizer without nitrogen.

The laboratory observations of Sievers and Holtz concerning the effect of nitrogen on the conservation of organic matter is therefore not substantiated by long-time field experiments.

The economic importance of acid phosphate and potash used in connection with a grain rotation is emphasized by the fact that for 40 years without the use of applied nitrogen this treatment has maintained crop yields and soil organic matter. (Pennsylvania field plat experiments.)

The value of PK treatment in influencing the fixation of atmospheric nitrogen is shown from the fact that a total of 1,616 pounds of nitrogen have been removed by cropping on the Pennsylvania plats in 40 years and still the soil thus treated contains more residual nitrogen and organic matter than the plats treated with nitrate of soda or sulfate of ammonia.

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