The Effect of Different Fertilizer Treatments on Humus Quality

Two decades of research in Sweden show differences in composition and quantity of humus throughout soil layers from varying fertilizer applications.

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A FIELD EXPERIMENT with four-year crop rotations was conducted at Järna, Sweden (59°N, 18°E) beginning in 1958. Integral effects on produce and soil as influenced by different types of soil amendments from conventional to organic were described in several reports [see Pettersson and Wistinghausen, 1977]. Our contribution in this endeavour concerns apparent changes in the humus chemistry after almost two decades of treatments.

Soil humus may be suspected to be exceedingly complex, as it derives from vastly different plant and animal matter. Yet, elemental composition as with refined chemical description reveal a surprising conformity of humus formed in different soils under widely varying climatic conditions [Schnitzer and Kahn, 1972]. Soil humus is derived from soil organic matter and it is a matter of definition how to clearly separate the two. Organic matter is often consumed with surprising rapidity in soils; yet, in some circumstances it may persist for periods approaching 2000 years [Scharpenseel, 1971; Campbell, 1967].

We view humification as a combination of biochemical degradation and microbial synthesis steps leading to the formation of humus substances with new properties not shared by the source materials.

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Classical chemical separation of humus distinguishes humic and fulvic acids, humates and humins. Humic and fulvic acids, resulting from alkaline digestion, may be grouped together as the most active of these fractions. Chemical deposition of humic and fulvic acids by inorganic cations, principally calcium and magnesium in near neutral soils and iron and aluminum in acid soils, results in the formation of humates (also fulvates) which are largely insoluble and arbitrarily classified as either organo-mineral complexes, chelates, or in classical German usage, gray humic acids. Finally, humins may be regarded as the most highly insoluble and inactive

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humus fraction, believed to be deposited with soil minerals, either within their lattices or on their surfaces, depending on the minerals and the humic acid composition [Kononova, 1966].

The emphasis on chemical structure of humus almost overshadows the fact that it is largely of microbiological origin [Williams, 1902; Kononova, 1966; Kühnelt, 1961; Hartmann, 1965]. Together with this trend, the conventional predominance of use of inorganic nutrients for food and fiber production has tended to obscure our understanding of the significance which organic matter and humus bear for soil productivity [Eckholm, 1976; Flaig et al., 1977; Pauli, 1961].

Materials and Methods

The field experiment: The field layout originally embraced eight different fertilizer variants within a four-fold crop rotation (wheat - clover/grass - potatoes - beets) designed so that each crop was growing each year (see Diagram 1). Although we investigated all the original eight variants, we have confined our results to a description of the five main treatments, as follows:

Variant	Treatment
I.	farmyard manure, composted with addition of 1% meat and bone meal. each; 4.4 metric ton/hectare/year dry basis
II.	farmyard manure, fresh, with meat and bone meal, as above; 4.1 t/ha/yr dry basis
III.	farmyard manure, fresh; 2.2 t/ha/yr combined with inorganic NPK 15:13:22 kg/ha/yr
IV.	control, no treatment
V.	inorganic NPK; 62:53:86 kg/ha/yr (medium rate)

key: metric ton/ha & kg/ha x 0.9 gives US ton/a & lb/a, resp.

In actuality there were two almost identical compost treatments and three inorganic NPK treatments implementing low, medium and high application rates. Fertilizers were not actually applied every year, but on a four year basis with 40 and 60% put down on the potato and beet rotations, respectively, with the exception that where inorganic treatments were used, 20% of the 4-year allotment for nitrogen was applied to the wheat rotation.

Humus determination: Soil samples for the topsoil (0-10cm) and subsoil (25-35cm) were taken in Fall 1976 from each of the wheat parcels, air dried, ground to pass a 1 mm sieve and stored 6 months prior to analysis. Humic and fulvic acids (hereafter referred to jointly as humic acids) were extracted
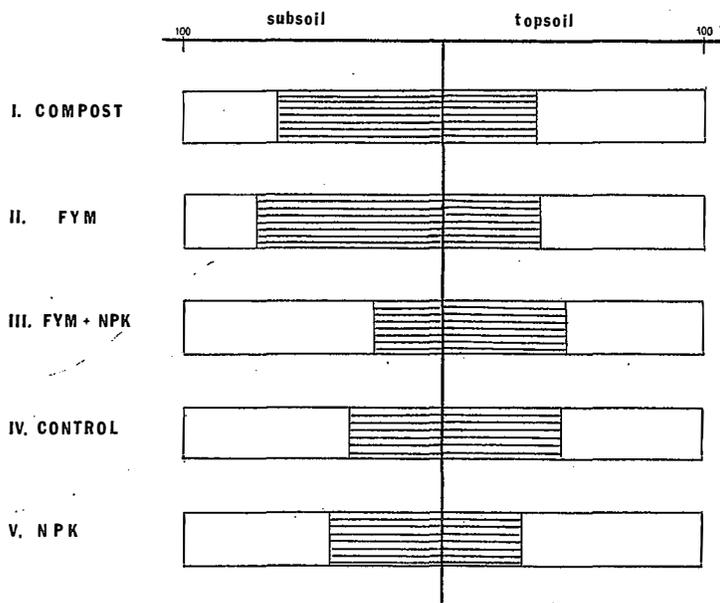
Diagram 2. Relative percent humic acids ▤ and humins ☐ in the topsoil and subsoils after 19 years vary treatments.

TABLE 1. Relative content of humic acid and humin in topsoil and subsoil samples

Treatment			% Humic acids	% Humins
I.	Compost	topsoil	36	64
		subsoil	63	37
II.	FYM	topsoil	37	63
		subsoil	72	28
III.	FYM & NPK	topsoil	47	53
		subsoil	27	73
IV.	Control	topsoil	45	55
		subsoil	36	64
V.	Inorgan. NPK	topsoil	30	70
		subsoil	44	56

TABLE 2. Humic acid pool for the topsoil and subsoils

Treatment	Humic Acids, kg/ha	% change over control
I. Compost	48,800	+ 42
II. FYM	48,300	+ 40
III. FYM+NPK	24,300	− 29
IV. Control	34,400	0
V. NPK	29,700	− 14

note: data adjusted for soil bulk density

TABLE 3. Humate humic acid pool for the topsoils

Treatment	Humates, kg/ha	% change over control
I. Compost	13,700	+ 56
II. FYM	11,000	+ 25
III. FYM+NPK	11,400	+ 30
IV. Control	8,800	0
V. NPK	10,900	+ 24

TABLE 4. Quotient 465/665nm of humic acids

Treatment	Topsoil	Subsoil
I. Compost	8.1	7.0
II. FYM	8.4	7.6
III. FYM+NPK	8.2	10.5
IV. Control	7.2	8.3
V. NPK	8.5	9.3

particularly in relation to the type of soil management. In our view, the results also underscore the significance of the available humic acid pool of soils in relation to these features.

Conclusion

Cursory review of the currently increasing wealth of information relating to effects of organic amendments on soil structure and productivity shows that these effects are exceedingly broad, influencing such features as water holding capacity, compactibility, cation exchange capacity, chelating ability, nitrogen release, phosphorus fixation and more [Schnitzer and Kahn, 1972; Russel, 1974; Lårsen, 1968]. Additionally, there remains little doubt any more as to the fact that

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Humic material cycling in soils must be researched.

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humic acids, especially in their more available forms, are physiologically active constituents of the soil-plant system [Flaig et al., 1977; Prát, 1962; Ku-Tsen-Chui, 1962; Vaughan and Macdonald, 1976]. These physiologic attributes of humic substances, together with their physico-chemical traits, make it difficult to separate and distinguish the causes of alleged increases in soil productivity associated with organic treatment.

Although the foregoing field experiment was not set up with replications of individual treatments, precluding careful statistical analysis of the results, we nonetheless believe that the 19-year history of consistent management compensates for this deficiency. Under the soil and climatic conditions which obtain for the experiment, the various treatments have distinguished themselves clearly over the years [Pettersson and Wistinghausen, 1977].

On the basis of these results, it is not possible to pinpoint cause - effect mechanisms which have been influential in determining the whereabouts and condition of the humic consituents of the soils. The cycling of organic matter in soils, its dissolution, deposition and re-solubization, has a number of physical-chemical-biological corollaries not easily categorized as either cause or effect. The aforegoing results underscore in our view the importance of studying humic material cycling in soils, particularly in relation to source - sink cycles and their biological associations.

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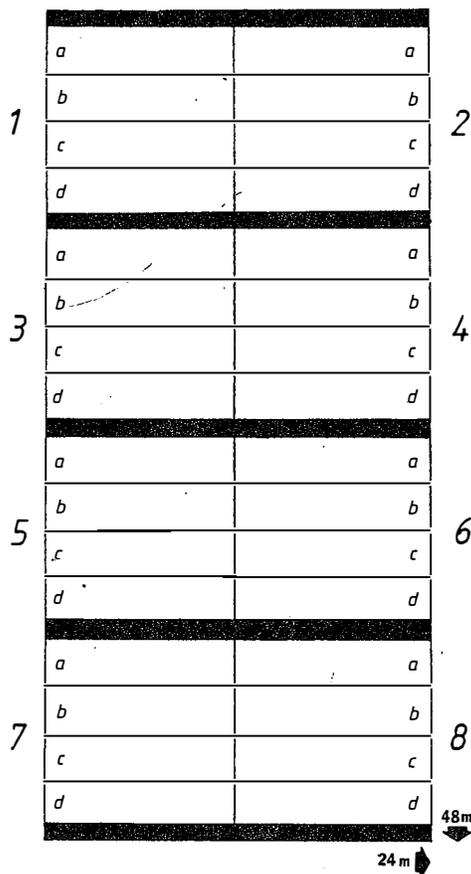
Diagram 1. Field layout for the Swedish experiments. Numbers refer to treatments; letters to rotations.

using 1) 0.1 N NaOH at 25°C and humic acids + humates using 2) 0.2 N NaOH + 0.2 M $Na_4P_2O_7$ (v+v) at 25°C. After an initial 6 hour extraction period for each method, the samples were decanted and re-extracted with fresh solution for the same period and the solutions combined for analysis, with all procedures performed in duplicate. The concentration of humic acids in aliquots was read spectrometrically against a calibration curve prepared from a humic acid standard preparation (supplier: Fluka Laboratories, Switzerland) according to Springer [1948]. We relate the extracted quantity of humic acid to the organic matter content determined by the Lichterfelder wet oxidation technique [Schlichting and Blume, 1966] to arrive at per cent humic acid, the difference from 100 representing the non-extractable humin portion. By subtracting the quantity of humic acid determined for the second extraction procedure from that of the first we arrive at humate humic acid. The slope of the optical absorbance curve in the visible range of the spectrum was de-

termined from the ratio of absorbance between two wavelengths, 465 and 665 nm [Welte, 1955; Scheffer, 1952]. Data for soil bulk density, soil pore space, number of earthworm *(Lumbricus terrestris)* canals, dehydrogenase activity and CO_2-respiration for these soils were supplied us by the institutes which collaborated in this study.

Statistical analysis: The field experiment did not incorporate replications and therefore it was not possible to statistically test the differences between individual treatments. In testing the significance of correlations between the treatment effects, we have used data from all original eight variants. To test the possible significance of differences between inorganic and organic treatment per se we have grouped the three strictly organic variants (compost 1, compost 2, and farmyard manure 3- see Diagram 1) as one type of treatment and the three inorganic variants (low, medium, high application rates- 6,7,&8 in Diagram 1) as the second type of treatment and conducted variance analysis on data from these variants.

Results and Discussion

In *Table 1* and *Diagram 2,* we depict the relative quantities of humic acids and humins for the topsoil and subsoil samples.

With the exception of treatment III (FYM + NPK), fertilization in general has tended to decrease the relative portion of humic acids in the topsoils and increase them in the subsoils in relation to the control. On an absolute basis, the available humic acid pool for the topsoil and subsoil has been increased with organic treatment and decreased with inorganic treatment, with the combination of manure and NPK (treatment III) responding much more like the inorganic than organic treatments (see Table 2).

When we group all the organic treatments as against the inorganic ones, as described earlier, the quantity of humic acids in the topsoil + subsoil samples is greater in the organic variants at a statistical level of 90% (i.e. 10% chance that differences are due to error) and for the subsoils alone the difference is statistically significant at the 95% level.

Additional extraction to release humic acids bound by inorganic cations as humates give the following data (see Table 3).

The least amount of inorganically

bound humic acids was observed in the control soil, and all fertilizers have brought an increase in levels, most markedly where the compost treatment has been used, a feature underscored by earlier work with compost [Springer, 1949].

The slopes of the humic acid absorbance curves are shown in Table 4.

In the topsoils the absorbance slope increases slightly with fertilization and paralleled an increase in organic matter (the correlation was not statistically significant). In the subsoils there is greater differentiation, with the absorbance slopes for the organic treatments declining over that of the control and with inorganic treatment increasing over the control. Here again, the combination of manure and inorganic NPK has given results more indicative of the inorganic than organic treatment. The observed absorbance slopes showed a close relation to the amount of humic acids available in the subsoils, declining as the humic acids increased. This relationship was highly significant (r = 0.86**) at the 99% level. We believe this fact must be interpreted in view of biological features, as will be discussed. A lower absorbance slope is seen as indicative of increased humification through polymerization and subsequent darkening of humic acid molecules [Welte, 1955; Scheffer, 1952; Schaefer, 1963; Hoffman, 1964].

In the topsoils the apparent changes in humic acids and humins do not show appreciable relationships to the type of soil treatments. However, in the subsoils they clearly do, and a number of the observed responses are closely related to each other. Here, an increase in humic acids in the subsoils parallels a decrease in compaction as measured by bulk density and an increase in water holding capacity measured as pore space; both relationships are highly significant at the 99% level (r= 0.86** and 0.84**, respectively). Additionally, the increase of humic acids parallels increases in biological activity as measured by CO_2-respiration, dehydrogenase enzyme activity and quantity of earthworm canals; the relationships are all significantly correlated at the 95% level (r= 0.73*, 0.78* and 0.76*, respectively). The nature of these relations between the various observed effects of different fertilizer treatments are evidence to us of the importance of biological features in soil humification processes,

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