

Short Communication

HUMIFICATION OF POLYPHENOL-RICH PLANT RESIDUES†

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In the tea fields of Sri Lanka, the amount of polyphenol-rich tea residues returned annually to tea soils, is very large (Visser, 1960) and therefore it was of interest to examine the implications to soil properties. Of particular importance were the reports that polyphenols participate in the formation of soil humic matter (Flaig *et al.*, 1975). I report the effect of phenol-rich tea residues after prolonged decomposition under greenhouse conditions on the humic matter status (Sequi *et al.*, 1975) of a tea soil. The relative importance of plant phenols and leaf nitrogen in the formation of humic matter is also examined.

The plant materials used as soil amendments were (1) tea shoot tips (2) mature tea leaf (3) a mixture (1:1, w/w) of treatments (1) and (2), (4) black tea (5) "Spent tea leaf" (6) Dadap leaf (*Erythrina lithosperma*) (7) Mana grass (*Cymbopogon confertiflorus* C. stend. stapf.) (8) Guatemala grass (*Tripsacum laxum* Nash) and (9) Tobacco leaf (*Nicotiana tobacum*). Mana grass and Guatemala grass are used extensively in the rehabilitation of tea lands while Dadap is grown as a shade tree in tea estates. "Spent tea leaf" is the residue of black tea after extraction with boiling water.

The plant materials were dried at 50°C for 16 h, ground in a Wiley mill to <0.5mm and were assayed for nitrogen (Kjeldahl method) and total phenols (Swain and Hills, 1959).

Greenhouse incubation

Five kg soil (air-dried, <3 mm, red-yellow podzolic, clay loam, pH 4.7, organic C=2.8%, N=0.17%) was thoroughly mixed with 25 g powdered plant material at the rate of 5g kg⁻¹ soil and incubated (25°C±2°, 65% WHC) for 4 months, after which, the soil was allowed to dry by withholding moisture for 1 week. The dry soil was then mixed with another increment (25 g) of powdered plant material and incubated under the earlier conditions. This process was repeated once more, following which the soil was air-dried and sieved < 2 mm. The total plant material added was 15 g kg⁻¹ soil and the total incubation period was 12 months. There were three replicates for each treatment placed in randomized block design.

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TABLE 1 — *Composition of plant residues used as soil amendments*

<i>Treatment</i>	<i>Total phenol (%)</i>	<i>N (%)</i>
(1) Tea shoot tips	24.39	4.54
(2) Mature tea leaf	12.00	3.55
Mixture (1:1, w/w) of (1) and (2)	18.80	4.13
Black tea	22.53	4.00
Spent tea leaf	7.55	3.30
Dadap leaf	2.10	4.93
Mana grass	1.03	1.08
Guatemala grass	1.13	0.86
Tobacco leaf	1.84	4.08

The composition of the plant residues used as soil amendments is shown in Table 1. For the first four treatments, namely Tea shoot tips, Mature tea leaf, Mixture and Black tea, total phenol content ranges from 12.00 to 24.30% while for the last four treatments i.e. Dadap, Mana, Guatemala and Tobacco, the range is from 1.03 to 2.10%. On a comparative basis, therefore, the former group could be classified as phenol-rich plant material while the latter could be referred to as phenol-poor plant material, and "Spent tea-leaf" falls intermediate between these groups.

Table 1 also shows that the phenol-rich residues have fairly high N contents which ranges from 3.55 to 4.54%. Of the phenol-poor residues, Dadap and Tobacco have comparably high N values, while the grasses Mana and Guatemala have relatively low N contents.

Humic matter

The humic matter (HM) obtained by 0.5 N NaOH extraction (Sequi *et al.*, 1975) contains a fair amount of non-humic material like carbohydrates and proteins (Mortensen and Himes, 1965). On acidification to pH 1, humic acid (HA) is precipitated and the non-humic components pass into the fulvic acid (FA) solution. The FA fraction therefore contains significant amounts of non-humic material in addition to the true FA's which are phenolic condensation products (Schnitzer, 1977). These two components of the FA fraction can be separated on Polyclar (PVP) column (Sequi *et al.*, 1975). The fraction retained on the column are FA's while the effluent would be the non-humic fraction (NHF). Aliquots of HM and NHF were therefore taken for determination of C and N.

According to Schnitzer (1977), humic substances are essentially phenolic heteropolymers and therefore the difference between HM and NHF would refer to the "true" humic matter (THM). In this study it was desired to evaluate the status of "true" humic matter and this was therefore evaluated as

$$\text{THM} = \text{HM} - \text{NHF}$$

Analysis of the true humic fractions and the non-humic fractions are presented in Table 2. Amendment with phenol-rich residues, in each instance has led to a statistically significant increase of THM-C as well as THM-N over that of control. Such an increase is absent in the case of soils receiving phenol-poor treatments. Further, in the case of soils amended with phenol-poor residues, although Dadap and Tobacco had a much higher leaf-N content than Mana or Guatemala, the THM-N of these four soils were not significantly different from each other.

Table 2 also reveals that the C-N ratio of THM of soils amended with phenol-rich residues are much lower than that of soils amended with phenol-poor residues. The former ranges from 17.0 to 25.0 with an average value of 21.3, while the latter ranges from 30.2 to 36.8 with an average value of 32.6. A narrower C-N ratio for the THM of soils amended with phenol-rich residues suggests a greater incorporation of N during THM formation in these soils. Coulson *et al.* (1960) have speculated that the fate of leaf N may be closely related to the kind and quantity of polyphenols remaining within the plant. They suggested that two processes may occur concurrently. On the one hand, the polyphenols may form complex structures by a bridging with basic N containing groups. On the other, polyphenols, if of the correct molecular range of size, may act as tanning agents capable of preserving protein from rapid decay. My results indicate that with tea polyphenols, the former process has occurred to a greater extent.

TABLE 2 — Analysis of organic matter fractions of amended soils

Treatment	True humic matter (THM)			Non-humic fraction (NHF)		
	C*	N†	C-N ratio	C*	N†	C-N ratio
Tea shoot tips	9.16	0.54	17.0	3.95	0.58	6.8
Mature tea leaf	7.89	0.32	25.0	4.85	0.60	8.0
Mixture	8.56	0.40	21.4	4.49	0.61	7.4
Black tea	8.86	0.41	21.6	4.94	0.69	7.2
Spent tea	7.82	0.31	25.2	4.86	0.64	7.7
Dadap	7.68	0.24	32.0	4.17	0.70	6.0
Mana	7.73	0.21	36.8	4.13	0.61	6.8
Guatemala	7.56	0.23	31.5	4.01	0.60	6.7
Tobacco	7.84	0.26	30.2	4.35	0.69	6.3
Control	7.39	0.25	29.6	3.84	0.51	7.5
LSD ($P = 0.05$)	0.48	0.07	—	0.53	0.03	—

*C—mg C g⁻¹ soil.

†N—mg N g⁻¹ soil.

The correlation analysis presented in Table 3 shows that THM-C as well as THM-N have a very high positive correlation to plant phenol content, whereas they bear no correlation to plant-N content. This data illustrates the relative importance of plant phenols and plant-N in the formation of THM. The non-humic fractions are not correlated to either of these plant constituents.

TABLE 3 — Correlation coefficients between soil organic matter fractions and some chemical constituents of the soil amendments

Soil organic fraction	Soil amendment	
	Total phenols	Plant-N
True humic matter—C	0.98***	0.48
True humic matter—N	0.95***	0.55
Non-humic fraction—C	0.28	0.29
Non-humic fraction—N	0.23	0.43

***Significant at the 0.01 probability level.

I conclude that a higher content of polyphenols in the decomposing plant residue leads to: (i) the formation of larger amounts of true humic matter and (ii) the incorporation of greater proportions of nitrogen into the true humic matter formed.

The practical implication of these observations is that humification of polyphenol-rich residues leads to the formation of appreciable amounts of N-rich humic matter.

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