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Decomposition and Humification in Soil of Plant Residues Differing in Chemical Composition

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Abstract: Soil samples amended with powdered plant material of wheat, maize, and sesbania were incubated for 8 weeks at moisture content of 60% of the maximum water holding capacity and 22-26°C for 8 weeks. At 0, 2, 4 and 8 weeks of incubation, portions of soil were analyzed for i) total C and its distribution in humic and fulvic acid fractions and ii) optical properties of humic acid. Humus fractions were extracted with both sodium hydroxide (NaOH) and sodium pyrophosphate ($\text{Na}_4\text{P}_2\text{O}_7$). Higher amounts of humus C were extracted with NaOH than with $\text{Na}_4\text{P}_2\text{O}_7$; the treatment differences were more obvious in former. Organic amendment resulted in higher amounts of humic and fulvic acid; more humus C being found in soil amended with maize and wheat. More N was determined in humic acid compared with fulvic acid following the extraction of soil with NaOH. Nature of organic amendment and the extractant used had a significant effect on C/N ratio of humic compounds. Optical density of the humic acid fraction decreased at the increasing wavelength and was correlated significantly with the C content of humic acid. Duration of incubation and nature of amendment had a significant effect on the polymerization and maturity of the humic acid fraction.

Key words: Humification, maize, organic amendment, sesbania, wheat

Introduction

Plant residues added to the agricultural soils vary widely in chemical composition depending upon their origin and conditions under which they are produced. Major chemical constituents of plant residues which enter or remain in soil consists generally of about 30-65% cellulose and hemicellulose, 10-25% lignin, and small percentages of proteins, fats, simple sugars, aliphatic acids, phenols and numerous other substances. Some plant residues, like wheat and rice straw, are rich in cellulose and low in lignins. Others may have a higher proportion of soluble materials, while still others may be rich in lignins.

Upon addition to the soil, the fate of these residues is determined to a considerable extent on the proportion of different chemical constituents. In general, a greater portion of the residual carbon is oxidized by the soil microbes and converted into CO_2 and H_2O (Azam *et al.*, 1985; Haider and Azam, 1982; Stenger *et al.*, 2001; Thuries *et al.*, 2001). During the process of decomposition, some of the residual carbon is incorporated into microbial biomass, while a substantial proportion is transformed into relatively stable humic substances (Azam *et al.*, 1985; Kassim *et al.*, 1981a,b; Stott *et al.*, 1983). Plant residues rich in sugars, organic acids, and polysaccharides are rapidly decomposed and thus make a meager contribution to the humus (Azam *et al.*, 1985; Thuries *et al.*, 2001). However, the residues rich in lignins decompose more slowly but become a major source of soil humus (Haider and Martin, 1975; Kassim *et al.*, 1981a,b).

In Pakistan, the agricultural soils are low in organic matter contents, especially the stable humus fraction (Azam, 1988). This is because of two main factors i.e., low organic matter returns to the soil and the typical agroclimatic conditions (high temperatures in particular) that are highly conducive for a rapid loss of soil organic matter. In order to sustain agricultural productivity, a desirable level of soil organic matter needs to be maintained through repeated applications and proper management. However, maintenance of organic matter contents will depend on the chemistry of the material destined for soil application and the

conditions under which it is decomposed. Keeping in view the agroclimatic conditions and the plant residues available in Pakistan, an experiment was conducted to study i) the rate of decomposition of plant residues (wheat, maize, sesbania) differing in chemical composition, ii) the changes in soil organic matter fractions during the process of decomposition and iii) optical properties as well as C and N contents of stable humus fraction i.e. humic acid.

Materials and Methods

Soil: The sandy-loam soil used in the studies was collected from experimental fields of Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, by digging surface soil to a depth of 15 cm. Air-dried and sieved (< 2 mm) soil had the following physico-chemical characteristics: organic C, 0.6%; total N, 0.09%; $\text{NH}_4^+\text{-N}$, $4.2 \mu\text{g g}^{-1}$ soil; $\text{NO}_3^- + \text{NO}_2^-\text{-N}$, $67.9 \mu\text{g g}^{-1}$ soil; pH (1:2.5, soil:water suspension), 7.4; EC, 0.8 dSm^{-1} ; water holding capacity, 25%; sand, 60%; silt, 21%; and clay, 19%.

Plant residues: Finely powdered straw of wheat, maize, and sesbania were used for incorporation in potted soil. Sub-samples of plant material were analyzed for total carbon (C), total nitrogen (N), 2N H_2SO_4 hydrolyzable C and hydrolyzable N (Table 1). The three types of residues generally differed in most of the characteristics. However, wheat material was entirely different from the other two, which among themselves were similar in several respects.

Table 1: Chemical characteristics of plant residues

Parameters	Plant material		
	Wheat	Maize	Sesbania
Total C, mg g^{-1}	390.71	352.36	354.66
% C	39.07	35.24	35.47
Total N, mg g^{-1}	4.88	20.92	25.56
% N	0.49	2.09	2.56
C/N ratio	80.00	16.84	13.88
Hydrolyzable C, mg g^{-1}	117.80	148.05	149.43
Hydrolyzable C, % of total C	30.15	42.02	42.13
Hydrolyzable N, mg g^{-1}	3.03	12.82	19.20
Hydrolyzable N, % of total N	62.09	61.27	75.13
C/N ratio of hydrolysate	38.85	11.55	7.78

Incubation experiment: Six kg portions of air-dried and sieved soil were placed in 64 plastic pots. Soil in four sets of 16 each was amended as follows: i) no amendment (control), ii) wheat straw at 0.5%, iii) maize straw at 0.5% and iv) sesbania straw at 0.5%. Moisture content of the soil was adjusted to 15% (w/w) with tap water and maintained at this level throughout the incubation by making up the weight loss. Incubation was carried out at 22-26°C for 0, 2, 4 or 8 weeks and managed in a way that all the samples were obtained on the same date. Portions of the soil were freeze-dried and analyzed for i) total C, ii) total N, iii) distribution of C and N in different humus fractions i.e. humic acid, fulvic acid, and humins. Humic acid fraction was further studied for optical properties under visible range (400-700 nm).

Analytical methods: For the determination of pH, EC, texture, and water holding capacity, methods of Anonymous (1954) were followed. Total N and mineral N ($\text{NH}_4^+\text{-N}$ and $\text{NO}_3^- + \text{NO}_2^-\text{-N}$)

were determined by Micro-Kjeldahl method (Bremner and Mulvaney, 1982; Keeney and Nelson, 1982). Organic C in soil and humus fractions was determined by wet digestion method, while humus fractions were obtained by the methods of Kononova (1961). However, both NaOH and Na-pyrophosphate were used for extracting humus. Optical properties of humic acid fractions were determined at 400, 500, 600 and 700 nm using Spectronic-21 (Bausch and Lomb, Germany). Carbon and N contents of humic acid and fulvic acid fractions were determined as referred to above.

Plant residues were also subjected to hydrolysis in order to determine the proportion of easily mineralizable C and N. One gram portions of the plant material were refluxed in 50 ml of 2N H₂SO₄ for 1h; the contents of the reflux flask filtered through a scintered funnel and the filtrate was analyzed for total C and N.

Statistical analysis: The data were subjected to analysis of variance (ANOVA) in completely randomized design with factorial arrangements of treatments. Standard deviation was determined using MS-EXCEL software.

Results and Discussion

In general, C content of the soil decreased with the time of incubation (Table 2). Although minimum C was determined in unamended soil, amendment with maize showed lowest C content of soil when three plant residues were compared. This was because of the low amount of C added in the form of maize. As a result, loss of C was also low from soil amended with maize material. Calculations based on % loss of C from the added material revealed maximum C mineralization from wheat and sesbania materials followed by that from maize. The loss of C from the added material can well be related with the proportion of its easily oxidizable component as well as on the lignin and N contents. Studies reported in the literature show a higher loss of C from easily oxidizable C sources like glucose, cellulose, and straw (Azam *et al.*, 1985; Haider and Azam, 1982; Kassim *et al.*, 1981a,b; Martin *et al.*, 1971). Thus plant materials high in soluble C compounds are bound to be rapidly decomposed. Even different C moieties of the same molecule may differ significantly in their susceptibility to loss as CO₂ (Azam *et al.*, 1985; Martin and Haider 1979). Studies reported by these and other workers show that side chains and methoxyl carbons of lignin polymers are more rapidly respired to CO₂ compared with ring carbons (Kassim *et al.*, 1981a,b; Stott *et al.*, 1983). Effect of particle size on the rate of decomposition and transformations has also been demonstrated (Rovira and Vallejo, 2002).

Soil samples obtained at different incubation intervals were extracted with 0.1M NaOH as well as with 0.1M Na₂P₄O₇ (Na-pyrophosphate) to determine the extractability of humic compounds (humic acid and fulvic acid). The extractability of the humic compounds is facilitated by the formation of ionic bonds between the anions of humic acids and cations of alkali and alkaline earth metals. As such, the humic acids are present in the form of organo-mineral complex and hence cannot be extracted with water. This is because of such reasons that extractants like NaOH and Na-pyrophosphates are used to obtain soil humic substances. The extracted material was partitioned into humic acid (HA) and fulvic acid (FA). In the present study, C and N contents of FA and HA were used as a quantitative measure of humic compounds. The data on fulvic acid C and humic acid C extracted with NaOH are expressed as mg g⁻¹ soil (Fig. 1). A higher amount of C was found in both FA and HA of amended than unamended soil. Among the three amendments, sesbania showed lowest FA-C (0.43 mg, average of 4 incubation intervals), while wheat straw and maize were almost similar. Almost similar trends were observed for HA (average for wheat, maize and sesbania being 0.32, 0.31 and 0.26 mg C g⁻¹ soil, respectively). The amount of FA-C and HA-C decreased with incubation time in all the treatments. This is possible as a good proportion of non-humified materials can also be extracted with NaOH which will be more during the early period of incubation. These materials are

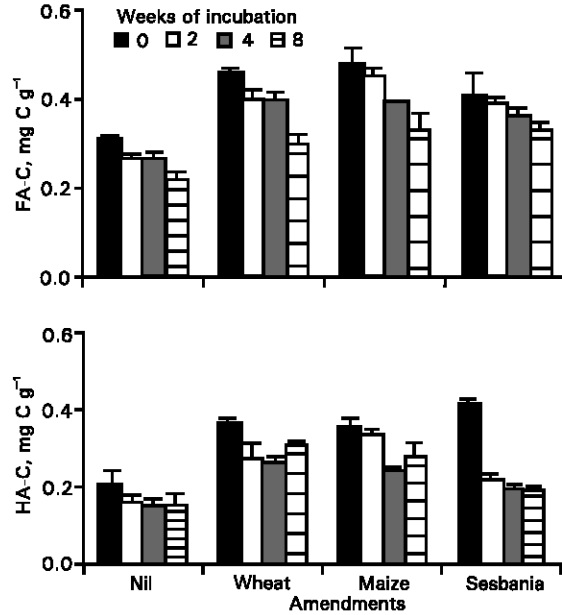


Fig. 1: Carbon content (mg C g⁻¹) of fulvic acid (FA) and humic acid (HA) extracted with NaOH.

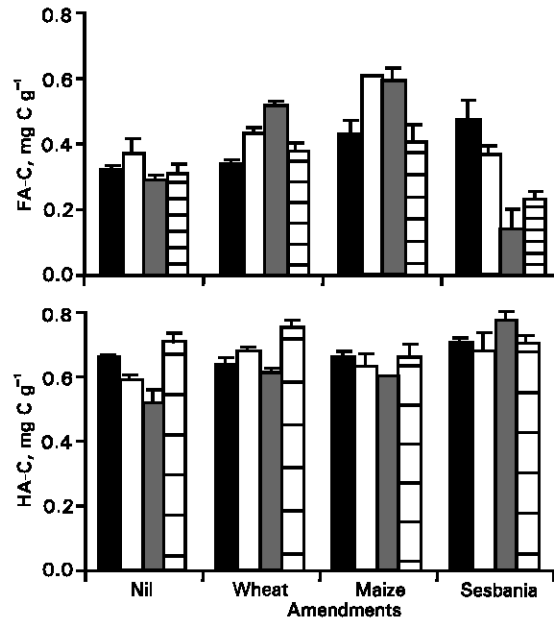


Fig. 2: Carbon content (mg C g⁻¹ soil) of fulvic acid (FA) and humic acid (HA) extracted with Na₂P₄O₇

however, less stable and undergo decomposition faster than humified materials. In all the treatments, FA-C was more than HA-C, an observation in conformity to other similar findings (Laura, 1973).

Significant differences were recorded for the contribution of wheat, maize and sesbania to both the humus components (data not shown). An increase of 32-68% in FA-C was obtained with organic amendments, the increase being the maximum with maize (61%) and minimum with sesbania (46%) when averaged over four incubation intervals. Increase in HA-C varied from 25% to >110%, again the increase was minimum with sesbania and maximum with maize (46.4 and 80.3%, respectively). This

Table 2: Loss of CO₂-C from soil amended with wheat, maize and sesbania material after different incubation intervals

Amendments	Weeks of incubation			
	0	2	4	8
mg C g⁻¹ soil				
Nil	6.22c [*]	6.00c	5.70c	5.59c
Wheat	8.40a	7.61a	7.01a	6.59ab
Maize	7.46b	7.06b	6.68b	6.41b
Sesbania	8.14a	7.43a	7.22a	6.88a
CO₂-C lost, mg g⁻¹ soil				
		0-2 weeks	2-4 weeks	4-8 weeks
Nil		0.22c	0.42d	0.63d
Wheat		0.79a	1.39a	1.81a
Maize		0.40b	0.78c	1.05c
Sesbania		0.71a	0.92b	1.26b
CO₂-C lost from the added material^{**}, mg g⁻¹ soil				
Wheat		0.57a	0.98a	1.29a
Maize		0.17c	0.37c	0.53c
Sesbania		0.49b	0.51b	0.74b
CO₂-C lost from the added material, % of added C				
Wheat		25.99a	45.04a	59.04a
Maize		13.98b	29.58b	42.55b
Sesbania		25.44a	26.55b	38.36c

Figures in a column (set of 3 or 4 values comparing plant residues) set sharing a similar letter are not significantly different from each other at 5% probability according to Duncan's multiple ranges Test.

^{*} *C added as wheat, maize and sesbania was 2.18, 1.23 and 1.92 mg g⁻¹ soil, respectively

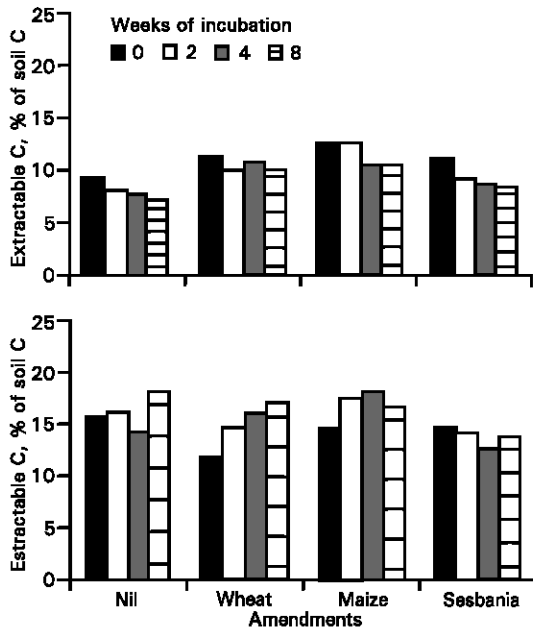


Fig. 3: Comparison of NaOH (top) and Na₄P₂O₇ (bottom) for extracting soil C

variation is due to the differences in chemical composition of the plant residues as well as the microflora that are involved in decomposition and transformations. Differences in microflora especially fungi in differently amended soils has been reported (Malik and Azam, 1978). In addition, sesbania contains relatively higher proportion of easily mineralizable C compounds hence making lesser addition to stable humus fractions (Table 1). Differences in chemical composition are reported to have a significant bearing on formation of humus compounds (Azam

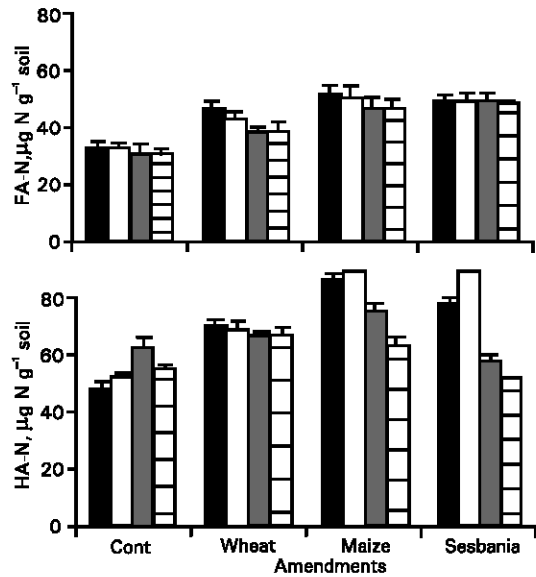


Fig. 4: Nitrogen content of fulvic acid (FA) and humic acid (HA) extracted with NaOH

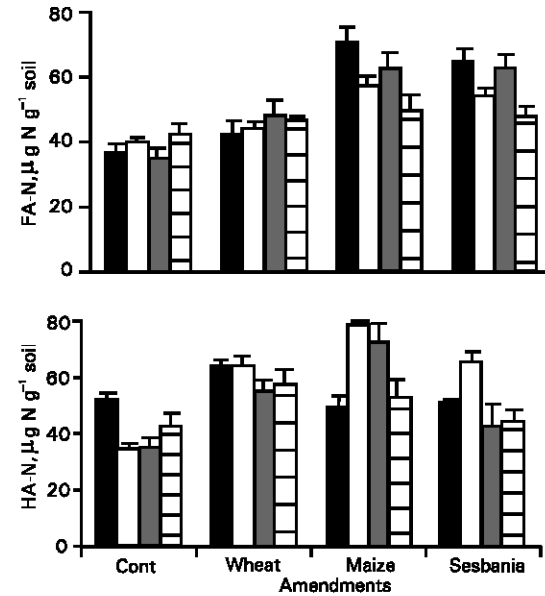


Fig. 5: Nitrogen content (µg N g⁻¹ soil) of fulvic acid (FA) and humic acid (HA) extracted with NaOH

et al., 1985; Kassim *et al.*, 1981a,b; Martin *et al.*, 1971; Stott *et al.*, 1983).

Extractability of humus C with Na-pyrophosphate was different as compared with that of NaOH (Fig. 2). The amount of FA-C ranged from 0.2 to 0.6 mg g⁻¹ soil in different treatments and at different incubation intervals. Compared to NaOH extractable FA, however, no definite trends were observed for the changes in FA-C at different incubation intervals. Maximum FA-C was extracted from maize amended soil (average of 0.51 mg g⁻¹ soil) and minimum (0.31 mg g⁻¹ soil) from Sesbania amended soil. Extraction of HA-C appeared to be more with Na-pyrophosphate than NaOH and varied from 0.55 to 0.7 mg C g⁻¹ soil. Different treatments did not show differences as clear as those observed for NaOH. A comparison of different amendments showed that

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Table 3: Optical density (at different wavelengths) of humic acid extracted with NaOH

Weeks	Amendments	Optical density (nm)				Extinction (E) ratios		
		400	500	600	700	E4/E5	E5/E6	E6/E7
0	Control	0.626c*	0.216d	0.126c	0.082c	3.76b	2.28ab	2.04b
	Wheat	1.060b	0.256c	0.124c	0.069d	4.66a	2.56a	2.37a
	Maize	1.183a	0.342b	0.183b	0.119b	3.40c	1.90c	1.59d
	Sesbania	1.168a	0.447a	0.273a	0.198a	3.71b	2.17b	1.89c
2	Control	0.489c	0.130d	0.057d	0.028c	3.76b	2.28bc	2.04b
	Wheat	0.848b	0.182c	0.071c	0.030c	4.66a	2.56a	2.37a
	Maize	1.119a	0.329a	0.173a	0.109a	3.40c	1.90c	1.59d
	Sesbania	0.805b	0.217b	0.100b	0.053b	3.71b	2.17b	1.89c
4	Control	0.463c	0.127c	0.056c	0.030b	3.65c	2.27a	1.87b
	Wheat	0.838a	0.194a	0.082ab	0.040a	4.32a	2.37a	2.05a
	Maize	0.851a	0.203a	0.085a	0.042a	4.19ab	2.39a	2.02a
	Sesbania	0.688b	0.177b	0.078b	0.039a	3.89b	2.27a	2.00a
8	Control	0.487c	0.162c	0.087c	0.056d	3.01c	1.86a	1.55a
	Wheat	0.849a	0.250a	0.136a	0.085b	3.40a	1.84a	1.60a
	Maize	0.846a	0.263a	0.143a	0.095a	3.22ab	1.84a	1.51a
	Sesbania	0.629b	0.200b	0.105b	0.069c	3.15bc	1.90a	1.52a

Table 4: Optical density (at different wavelengths) of humic acid extracted with Na-pyrophosphate

Weeks	Amendments	Optical density (nm)				Extinction (E) ratios		
		400	500	600	700	E4/E5	E5/E6	E6/E7
0	Control	1.01b*	0.44a	0.23a	0.10a	2.29a	1.89a	2.45a
	Wheat	1.09a	0.46a	0.24a	0.10a	2.34a	1.92a	2.44a
	Maize	1.09a	0.46a	0.24a	0.10a	2.36a	1.92a	2.41a
	Sesbania	1.06ab	0.46a	0.24a	0.10a	2.32a	1.95a	2.42a
2	Control	1.06ab	0.47a	0.25a	0.10a	2.25a	1.88a	2.41a
	Wheat	1.02b	0.44a	0.23a	0.10a	2.31a	1.91a	2.46a
	Maize	1.09a	0.47a	0.24a	0.10a	2.35a	1.91a	2.43a
	Sesbania	1.06ab	0.45a	0.24a	0.10a	2.35a	1.91a	2.41a
4	Control	1.07b	0.47b	0.25bc	0.11a	2.26a	1.88a	2.39a
	Wheat	1.22a	0.52a	0.28a	0.12a	2.34a	1.88a	2.41a
	Maize	1.08b	0.46b	0.239c	0.10a	2.35a	1.93a	2.44a
	Sesbania	1.11b	0.47b	0.25bc	0.103a	2.34a	1.89a	2.44a
8	Control	1.38a	0.61a	0.33a	0.14a	2.26a	1.840a	2.322a
	Wheat	1.37a	0.59a	0.31a	0.13ab	2.33a	1.876a	2.361a
	Maize	1.31a	0.56a	0.30a	0.125b	2.35a	1.878a	2.368a
	Sesbania	1.30a	0.56a	0.30a	0.126b	2.31a	1.877a	2.381a

*Figures in a column (set of 4 values each) sharing a similar letter are not significantly different from each other at 5% probability according to Duncan's multiple ranges test.

except for 3 occasions, generally an increase in FA-C and HA-C was observed (data not shown). Maximum %increase in FA-C was observed in case of sesbania amended soil, while maize amendment caused a maximum increase in HA-C. In general, wheat and maize amendments behaved similarly in terms of carbon addition to humus fractions.

It is interesting to note that the two extractants released different amounts of FA-C and HA-C from soil. While differences in extracting FA-C were not clear, Na-pyrophosphate caused complete extraction of humic acid compared to NaOH since different treatments showed lesser differences. Another observation was that the increase in FA-C and HA-C due to organic amendments was highly variable with the two extractants. When extracted with NaOH, different amendments showed 30-65% increase in FA-C and 25-110% in HA-C. In comparison, when extracted with Na-pyrophosphate, a maximum increase in FA-C and HA-C was found to be about 45%. In general, different solvents have been proposed and used to extract humic compounds of different molecular weights (Kononova, 1961, 1966; Schnitzer and Khan, 1972). Nevertheless, the most common extractants have been NaOH and Na-pyrophosphate used singly or in combination (Schnitzer and Khan, 1972, 1978).

Comparison of NaOH and Na-pyrophosphate for their efficiency in extracting soil C, expressed as % of soil-C extracted (Fig. 3). Of the two extractants, Na-pyrophosphate extracted about 15% of the soil C, while not more than 11% of the soil C was extracted

with NaOH from differently treated soil. The difference may be attributed to the type of material being extracted by the two. Sodium pyrophosphate is reported not only to extract the humic compounds but organomineral substances as well. The extraction of soil C with NaOH was more for amended than unamended soil samples, and decreased with the time of incubation. In comparison, Na-pyrophosphate extracted a higher proportion of soil C, but the amendments had no clear effect on percent extractability of the soil C. Time of incubation also did not show any specific trends as regards extractability of soil C with Na-pyrophosphate. It would appear that NaOH was relatively more specific in extracting humus compounds as compared to Na-pyrophosphate.

Humus components extracted from soil were also analyzed for N content (Fig. 4 and 5). On per gram soil basis, HA extracted with NaOH contained higher amounts of N that ranged from 50-90 $\mu\text{g g}^{-1}$ soil, while FA contained about 33-50 $\mu\text{g N g}^{-1}$ soil in different treatments (Fig. 4). In general, FA-N decreased with the time of incubation, whereas a decrease in HA-N was more apparent. Soil amendment had a positive effect on FA-N, the three amendments being not very different. On an average, 4.2.4, 50.4 and 50.1 $\mu\text{g N g}^{-1}$ of soil amended with wheat, maize and Sesbania, respectively.

Humic acid N also increased with the amendment, the increase being maximum with maize and almost similar with wheat and sesbania (average of different incubation intervals being

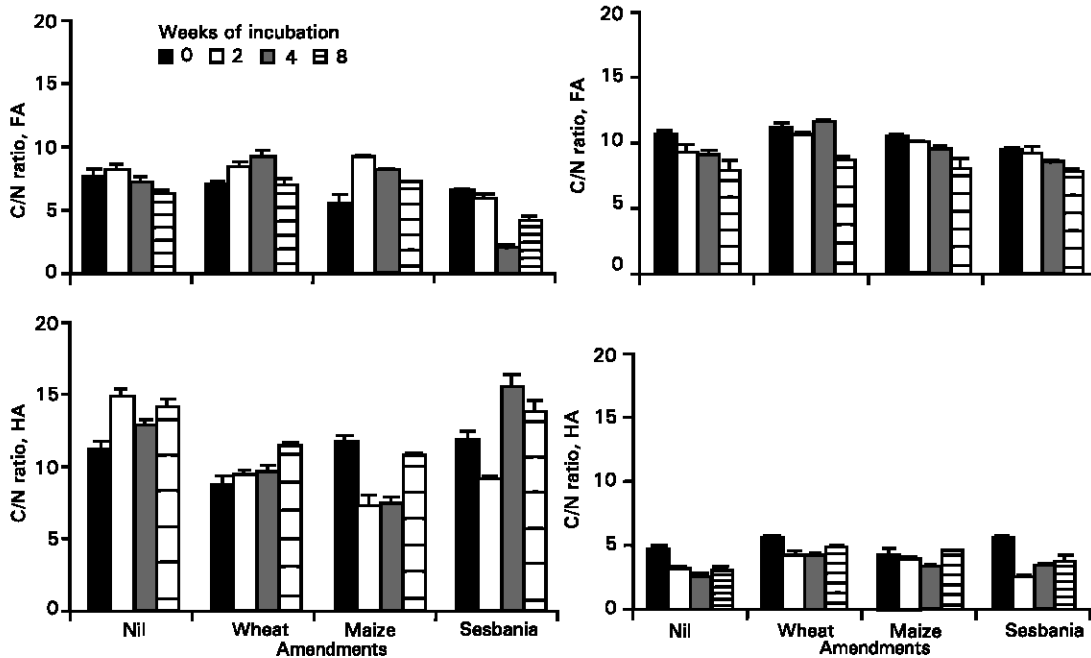


Fig. 6: C/N ratios of FA and HA extracted with NaOH (right) and $\text{Na}_2\text{P}_2\text{O}_7$ (left)

compared). These results were different than those obtained for FA-C and HA-C extracted with NaOH in which more C was found in FA as compared to HA.

Results show a relatively similar amount of N (average of all treatments) in FA and HA when extracted with Na-pyrophosphate (Fig. 5). Different soil amendments had a positive effect on the amount of N in both FA and HA. A decrease was generally observed with the prolonged incubation period. In soil amended with wheat, FA-N was slightly more than that in unamended soil, while HA-N was substantially higher. Lowest amount of HA-N was found in sesbania treated soil.

A greater proportion (53-66%) of the N extracted with NaOH was found in HA, while a similar proportion was recovered as FA in Na-pyrophosphate extract (data not shown). Soil treatments did not appear to affect significantly the percentage distribution of extractable N. However, relatively higher percentage of N extractable with NaOH was found in HA of unamended soil. Almost similar was true for Na-pyrophosphate. When expressed as percentage of soil N extractable with NaOH or Na-pyrophosphate, different amendments had a positive effect. The two extractants were not very different in extracting soil N and the time of incubation did not have a consistent effect on the extractability.

Fulvic acid extracted with Na-pyrophosphate had a C/N ratio ranging from 2.04 to 9.44, with an average value of 6.93. C/N ratio of HA was much wider ranging between 7.93 and 16.12 with an average value of 12.57 (Fig. 6). The trends in NaOH-extractable FA and HA were different from those observed when Na-pyrophosphate was used as an extractant. In this case, FA had a wider C/N ratio ranging from 7.71 to 11.64, while HA showed a range of 2.44 to 5.38; the average for the two ranges was 9.87 and 3.84, respectively. Thus the extractants were targeting different organic molecules. While some decreasing trend with incubation time in C/N ratio of FA extracted with NaOH was obvious, no such specificity was observed for Na-pyrophosphate. Organic matter amendments did not have a significant effect on the C/N ratio of FA and HA extracted with NaOH. However, when Na-pyrophosphate was used, FA obtained from sesbania-amended soil had a narrower C/N ratio compared to other treatments.

Optical density or absorbance in the visible range is often used as a measure of the content of humic compounds in the alkaline or neutral salt extracts (Kononova, 1966; Schnitzer and Khan, 1972, 1978). In addition, the changes in optical density as well as extinction ratios (e.g., E4/E5, ratio of absorption at 400 and 500 nm) has been used as a measure of the stability and extent of polymerization of the extracted humic compounds especially humic acid (Kononova, 1966; Schnitzer and Khan, 1972). Kononova (1966) believed that the magnitude of ratios especially of E4/E6 is related to the degree of condensation of the aromatic C network, with a low ratio indicative of relatively high degree of condensation of aromatic humic constituents. Conversely, a high E4/E6 ratio reflects a low degree of aromatic condensation and infers the presence of relatively large proportions of aliphatic structures. In the present studies, optical density of HA extracted with NaOH and Na-pyrophosphate was measured at 400, 500, 600 and 700 nm and extinction ratios of E4/E5, E5/E6 and E6/E7 calculated. A general decrease in optical density at higher wavelength was observed. Such a decrease in optical density at higher wavelengths is a characteristic of humic compounds. Higher optical density at shorter wavelength is due to the increased mobility of electrons over aromatic carbon "nuclei" and over unsaturated structures conjugated with these "nuclei" (Kononova, 1966). In addition, light absorption of humic substances appears to increase with i) an increase in the degree of condensation of the aromatic rings (Kononova, 1966), ii) ratio of carbon in aromatic nuclei to carbon in aliphatic side chains, iii) total carbon and molecular weight.

In general, absorption of HA extracted with NaOH decreased till 4th week for control and wheat amendment followed by increase after 8 weeks. While in maize and sesbania, it decreased till 8th week (Table 3). A comparison of different soil treatments did not show sharp differences in optical density measured at 400 nm. At higher wavelengths, however, the differences were more obvious. Wheat, maize and sesbania amendments did cause an increase in the absorption of HA as compared to control. The optical density was significantly correlated (values of "r" ranging between 0.8 and 0.95) with the C content of HA, correlation being more close at 400 nm than at the higher wavelengths. It is possible therefore to

determine the C content of HA simply by measuring optical density at 400 nm rather than by going through lengthy procedures. Similar conclusions had been reached in earlier reports (Azam, 1988). Extinction ratios E4/E5 ranged between 3 and 4.7, maximum being for wheat at each incubation interval. In each case, E6/E7 values were reduced to approximately half suggesting a similar slope and polymerization of the humic acid component. Humic acid extracted with Na-pyrophosphate showed significantly higher optical density than that extracted with NaOH (Table 4). However, there was no significant correlation between C content of HA and the optical density as observed for HA extracted with NaOH. In addition incubation time and type of amendment had no significant bearing on optical density of HA. Extinction ratios of E6/E7 were significantly higher than E5/E6 and almost similar to that of E4/E5. Compared to these results, the extinction ratios of HA extracted with NaOH decreased consistently with the wavelength. These differences suggest that NaOH and Na-pyrophosphate target different chemical entities for extraction. Apparently, NaOH was more selective and extracted the humic compounds in quantities as could be expected. Hence, NaOH could be a more reliable extractant of humic compounds compared to Na-pyrophosphate.

In summary, plant residues differing in chemical composition has a significant bearing on the amount and characteristics of soil humus. Apparently, wheat material proved to be a better source for humus synthesis by microbes despite a lower proportion of hydrolyzable C. Maize and sesbania which were similar in many respects contributed differently to soil humus probably due to the differences in the microbial population being supported. Studies are underway on microbial dynamics during the decomposition of these plant residues.

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