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Short Communication

Nitrogen and Sulphur Release from Added Millets and Oilseeds Residues in Indo-Gangetic Black and Alluvial Soils of Varanasi

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Decomposition of organic materials is an essential process for the release of nutrients in soils that can be used by the growing crops. Crop residues are highly carbonaceous materials having more variability in carbon (C) to nitrogen (N) ratio (C:N) which determine the rate of their decomposition and nutrient release pattern. Higher quality of crop residues having high N concentration, low lignin and cellulose concentrations and low C:N and lignin:N ratios often result in high N mineralization rate. In contrast, low-quality residues having lower N mineralization rate that can negatively influence plant available N due to their effect on N immobilization (Manzoni *et al*. 2008). Mineralization of sulphur (S) in soils is largely mediated by biological activity and is controlled by soil chemical and physical properties (Pirela and Tabatabai 1988) and type of organic residues added (Islam and Dick 1998).

Varanasi district lies between 25.14° and 25.23° N latitude and 82.56° and 83.03° E longitude. Indo-Gangetic alluvial soil falls under Inceptisol (Typic Ustochrepts) is formed by deposition of alluvium by the river Ganges. This soil constitutes a major area in Varanasi and is one of the most productive soils. Black soil, locally known as *karail,* falls under Vertisol (Chromusterts) and is developed in the Gangetic alluvium under waterlogged condition in the district. Recently, widespread N and S deficiencies have been reported in black and alluvial soils of Varanasi district (Singh 2018). Intensive cultivation with high yielding varieties, imbalanced fertilization and limited manuring have aggravated the deficiencies of available N and S in these soils. However, very little information is available on release of N and S in soils with added crop residues in Indo-Gangetic black and alluvial soils of Varanasi. Therefore, the present investigation was carried out to study the release pattern of N and S with added crop residues like millet (pearl millet and finger millet) and oilseed (mustard and sunflower) residues under laboratory incubation.

The composite bulk surface soil samples (0-15 cm) from black and alluvial soils were collected from Shahanshahapur village under Araziline block of Varanasi district. These samples were ground in a wooden pestle and mortar and passed through a 2-mm sieve. Residues of millets (pearl millet and finger millet) and oilseeds (mustard and sunflower) were collected from the farmer's field of Varanasi district just before harvesting of crops in the year 2018-19. These crop residues were washed with running tap water, rinsed three times with distilled water, dried at 65 °C for 48 h, milled and passed through a 1-mm sieve. Triplicate samples of each crop residue were taken and analyzed for their content of total C, total N and total S. A laboratory incubation experiment with black and alluvial soils was carried out to study the release pattern of N and S from the added crops residues. The experiment was laid out in a factorial completely randomized design with four replications. Treatment consisted of: T_1: Control, T_2: Pearl millet residue, T_3: Finger millet residue, T_4: Mustard residue and T_5: Sunflower residue, and two type of soils (black and alluvial).

One hundred eighty plastic bottle of 100 mL capacity each were used for the incubation study and filled with 50 g of processed air-dry soil. A known amount of 0.5 g of each crop residue was mixed thoroughly into the soil. After imposing the treatments, moisture content in the soils was maintained at field capacity by adding 11 mL distilled water in black soil and 9 mL distilled water in alluvial soil, respectively. The bottles were sealed tightly and incubated for 0, 12, 24, 36, 48 and 60 days at room temperature. After each incubation period, the soil samples were drawn, air-dried, ground and analyzed for available N and S contents.

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Table 1. Characteristics of the experimental soils

Characteristics	Black soil	Alluvial soil
Sand (%)	43.2	33.4
Silt (%)	17.9	45.2
Clay (%)	38.6	20.2
Texture	Clayey	Sandy loam
Water holding capacity (%)	53.4	39.1
pH (1:2.5 soil: water)	8.3	7.7
Organic C (g kg^{-1})	5.9	4.7
Total N (mg kg^{-1})	587.2	451.3
Available N (mg kg^{-1})	130.1	115.3
Total S (mg kg^{-1})	315.0	234.0
Organic S (mg kg^{-1})	237.0	161.0
Available S (mg kg^{-1})	7.1	8.3
C:N	10.1	10.4
C:S	18.7	20.1

Processed initial soils were analyzed for pH, texture and water holding capacity using standard methods. Organic carbon was determined by wet oxidation method of Walkley and Black (1934). Total N was determined by digesting soil and crop residue samples using a semi-micro-Kjeldhal method. Total carbon in crop residues was determined by combustion method (Havlin and Soltanpour 1980). Total S in soil and crop residue was determined by wet oxidation (Tabatabai 1982). Soil organic S was estimated as difference between total soil S and 0.15% $CaCl_2$ extractable S. The available N in soils was estimated the method of Subbiah and Asija (1956). Available S (0.15% $CaCl_2$ extractable) (Williams and Steinbergs 1959) was determined by turbidity method of Chesnin and Yien (1951). The results of the initial analyses of two soils used in the experiment are given in table 1.

The percentage of release of N and S over total amount of N and S added through crop residues was calculated as follows:

$$\text{Per cent release} = \frac{\text{Total N or S mineralized in amended soil} - \text{total N or S mineralized in unamended soil}}{\text{Amount of N or S added through crop residues}} \times 100$$

Details of composition of millets and oilseeds crop residue are given in table 2. Among different crops residue added, oilseeds exhibited significantly higher release of N compared to millets (Table 3). Results indicated that control soil without any

Table 2. Composition of different crop residues used in the incubation experiment

Crops residues	Total nutrient content (%)			Ratios			Amount added (mg kg^{-1} soil)	
	C	N	S	C:N	C:S	C : N : S	N	S
Pearl millet	52.3	0.51	0.10	102.6	523.3	523.3:5.1:1	51.0	10.0
Finger millet	49.8	0.52	0.11	96.1	452.4	452.5:4.7:1	52.0	11.0
Mustard	51.4	0.91	0.17	56.5	302.4	302.4:5.35:1	91.0	17.0
Sunflower	50.1	0.94	0.15	53.3	334.0	334.0:6.27:1	94.0	15.0

Table 3. Cumulative amount of N released in black and alluvial soils with addition of different crop residues

Crop residues	Nitrogen released (mg kg^{-1}) Period of incubation (days)					Mean
	12	24	36	48	60	
			Black soil			
T_1: Control	132.3	132.4	132.7	133.5	133.7	132.9
T_2: Pearl millet	132.5	132.7	133.8	137.5	139.8	135.3
T_3: Finger millet	132.6	132.9	134.3	141.8	142.0	136.7
T_4: Mustard	137.8	148.0	164.3	156.2	151.1	151.5
T_5: Sunflower	136.7	146.1	162.5	153.5	149.4	149.6
Mean	134.4	134.8	145.5	144.5	143.2	
CD (P=0.05)	0.09	0.13	0.06	0.03	0.02	
			Alluvial soil			
T_1: Control	117.5	117.8	118.4	118.9	119.1	118.3
T_2: Pearl millet	119.4	119.9	120.9	123.0	125.0	121.6
T_3: Finger millet	120.6	120.9	121.2	124.3	126.1	122.6
T_4: Mustard	129.3	136.9	148.3	146.0	143.9	140.8
T_5: Sunflower	128.7	135.3	146.3	144.5	140.3	139.0
Mean	123.1	126.2	131.0	131.3	130.9	
CD (P=0.05)	0.15	0.19	0.14	0.11	0.13	

amendment released a maximum of 133.7 and 119.1 mg kg^{-1} in black and alluvial soils compared at the initial values of 130.1 and 115.3 mg kg^{-1}, respectively. Addition of pearl millet and finger millet residues showed slow cumulative N release from 12 to 36 days and gradually increase the release between 48 and 60 days in both the soils. The maximum total N released from these amendment varied between 139.8 to 142 mg kg^{-1} in black soil and 125 to 126.1 mg kg^{-1} in alluvial soil. The N release pattern was similar in both the soils. The low N content and high C:N ratio of pearl millet and finger millet may have been largely responsible for initial slow decomposition and low net N release. This slow release may probably be due to the microbial population which use available soil N to decompose the residue. Nitrogen which is mainly organically bound in the form of protein, is released more slowly by microbial decomposition with wide C:N ratio crops. High lignin content and high C:N ratios in crop residues may interact with soil or plant residue, suppressing N availability due to formation of recalcitrant organic N forms (Bending and Turner 1999). Mustard and sunflower residues exhibited a rapid release of cumulative N between 12 to 36 days and declined in net release between 48 and 60 days. Mean values indicated that mustard and sunflower were released 151.5 and 149.6 mg kg^{-1} in black soil and 140.7 and 139.0 mg kg^{-1} in alluvial soil, receptively. The highest cumulative N release in soils treated with added mustard and sunflower residues may probably be due to low C:N ratio that favoured for rapid release of N during early days of incubation period.

Sulphur released during the incubation period varied considerably depending on type of soils and crop residues (Table 4). The S release in control as well as treatments with crop residues was higher in black soil than in alluvial soil. Cumulative S mineralization in both soils amended with pearl millet and finger millet residues followed slower rate from 12 to 36 days and relatively rapid release was found from 48 to 60 days. This may probably be due to immobilization–mineralization process of the added crop residue with high C:N ratio. Organic materials with high C:S ratios caused considerable immobilization of S, particularly during the early stages of decomposition (Somani and Saxena 1975). On the other hand, cumulative S release of added mustard and sunflower residues followed rapid release of S between 12 and 36 days and declined between 48 and 60 days. Treatments that received oilseeds residues such as mustard and sunflower released more S compared to millet residues such as pearl millet and finger millet. In unamended soils, the S release increased up to 60 days. The available S content increased with incubation period up to 36 days which might be due to microbial mineralization of organic form of S into inorganic form and decrease in S release during later stages at 48 and 60 days might be due to immobilization or fixation in soils. In oilseed crops, methionine and cysteine account for about 90% of total S, nearly all of these are present in the proteins (Allaway and Thompson 1966). Islam and Dick (1998) observed that addition of crop residue with a low C:S ratio had significantly higher accumulation of SO_4^{2-} than the control or the crop residues with higher C:S

Table 4. Cumulative amount of sulphur released in black and alluvial soils with addition of different residues

Crop residues	Sulphur released (mg kg^{-1})					Mean
	Period of incubation (days)					
	12	24	36	48	60	
			Black soil			
T_1: Control	7.3	7.6	7.9	8.4	8.8	8.0
T_2: Pearl millet	8.3	8.9	9.2	10.1	10.4	9.1
T_3: Finger millet	8.4	9.1	9.4	10.5	10.7	9.4
T_4: Mustard	12.1	14.8	15.5	14.3	13.7	14.1
T_5: Sunflower	11.6	13.9	14.1	13.5	13.0	13.2
Mean	9.5	10.9	11.2	11.4	11.3	
CD (P=0.05)	0.05	0.04	0.06	0.01	0.02	
			Alluvial soil			
T_1: Control	8.7	9.0	9.2	9.5	9.7	9.2
T_2: Pearl millet	9.3	9.6	9.8	10.7	11.1	10.1
T_3: Finger millet	9.8	10.1	10.3	11.0	11.4	10.5
T_4: Mustard	10.2	13.4	14.7	14.2	13.7	13.2
T_5: Sunflower	10.0	13.1	14.3	13.6	13.2	12.8
Mean	9.6	11.0	11.7	11.8	11.9	
CD (P=0.05)	0.02	0.07	0.04	0.05	0.02	

Table 5. Release of N and S as percentage of N and S added to soil through different crop residues

Crop residues	% of added N released		% of added S released	
	Black soil	Alluvial soil	Black soil	Alluvial oil
Pearl millet	12.0	11.6	16.0	14.0
Finger millet	16.3	13.3	17.3	15.5
Mustard	34.7	32.9	42.4	32.4
Sunflower	31.7	29.7	41.3	34.0

ratio. Similar pattern of S mineralization was also reported in Vertisol and Inceptisol by Sammy Reddy *et al*. (2002).

The net N and S mineralized as percentage of total N and S applied from millets and oilseeds residues are presented in table 5. Irrespective of crop residues, in general, the cumulative amounts of release of N and S were higher in black soil than in alluvial soil. Considering the net N mineralized as percentage of total N applied from pearl millet, finger millet, mustard and sunflower were 12.0, 16.3, 34.7 and 31.7%, respectively in black soil. The cumulative mineralized S as percentage of S added from mustard residue during different periods of incubation were higher (32.4 to 42.4%) as compared to sunflower (34.0 to 41.3%).

It may be concluded from the present experiment that soil amended with millets and oilseeds residues displayed wide variation of N and S release. This study suggests that residues of mustard and sunflower showed rapid release of N and S, thereby could be used for short-term supply of N and S to growing crops in black and alluvial soils. Crop residues with wide C:N ratio such as pearl millet and finger millet that showed slower release could be used for long-term supply of N and S to growing crops in both soils. The results may be useful for management strategies of N and S through addition of millets and oilseeds residues to restore soil health and crop productivity in Indo-Gangetic belt of Varanasi.

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