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Mineralization of carbon and nitrogen in zinc-treated rice field in calcareous soil

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Abstract : A field experiment was conducted during 2003-04 in a zinc deficient calcareous soil at Rajendra Agricultural University, Bihar. The experimental plot was under rice-wheat cropping system over last decade and the present study pertained to 21st (rice) and 22nd (wheat) crop in rotation. After completion of 10th cycle, rice and wheat were grown in rotation for present investigation. The carbon content of wheat straw decreased during first two weeks and beyond this period, the decline in carbon content of wheat straw continued till the end of the experiment. The N content of wheat straw enhanced considerably during 2nd and 11th week and with little change thereafter.

Additional key words : *Decomposition, wheat straw, nitrogen immobilization*

Introduction

The Indian Soils in general and Bihar soils in particular are poor in organic matter under rice-wheat cropping system. With imbalanced uses of fertilizer under intensive cropping system, soil organic matter content declines further as evidenced from the long term fertility experiment (Swarup *et al.* 1998). With increasing farm mechanization in rice-wheat cropping system, rice and wheat straw have become available as a surplus farm waste in large quantity in harvested area. This condition calls for incorporation of wheat straw into the soil after crop harvest, as an alternative to field burning. Incorporation of wheat straw is well recognized to have a beneficial effects on physical, chemical and biological properties of soils, however there is a risk of nitrogen immobilization by decomposing crop residues in soil and its possible potential adverse effects on the growth and yield of rice crop that follows. Though the long term effects of crop residues incorporation on rice-wheat production and changes in nutrient status of soil have been evaluated (Beri *et al.* 1995), there is lack of information on decomposition of wheat straw and mineralization of carbon and nitrogen in rice-grown calcareous soil. The objective of this investigation was to generate information on decomposition of wheat straw and carbon and nitrogen mineralization in zinc-treated calcareous soil.

Materials and Methods

A field experiment was conducted as a part of All India Coordinated Research Project on Micronutrients during 2003-04 in a zinc deficient calcareous soil at R.A.U., Pusa Farm in split plot design with four crop residue levels in main plots and four zinc levels in sub-plots. There were three replications in a plot sizes of 5.0 m x 2.0 m area. The plot is under rice-wheat cropping system for the last decade. After completion of 10th cycle, wheat and rice as 20th and 21st crops in rotation were grown. The experimental soil (0-15 cm) had pH 8.6, EC 0.36 dS m^{-1}, organic carbon 6.2 g kg^{-1}, Olsen's P 17.3 kg ha^{-1}, NH_4OAC-K, 162 kg ha^{-1} and DTPA-Zn 0.56 mg kg^{-1}. Four levels of crop residues *viz.* no crop residue (CR_0), 25% of straw produced (CR_{25}), 50% of straw produced (CR_{50}), 100% of straw produced (CR_{100}) were applied as treatments in main plots. The treatments were given to each crop in each year. The main plot was divided into 4 sub-plots in which treatments *viz.* no Zn (Zn_0), 2.5 kg Zn ha^{-1} ($Zn_{2.5}$), 5.0 kg Zn ha^{-1} ($Zn_{5.0}$) and 10 kg Zn ha^{-1} (Zn_{10}) were superimposed on crop residue levels only to the first crop as starter dose. Wheat cv H.D. 2733 and rice cv. Rajshree were grown as 20[th] and 21[st] crop, respectively during reported period of 2003-2004.

The extent of decomposition of wheat straw and carbon and N mineralization in rice field was determined by nylon mesh bag technique (Schinner 1996). Sample of wheat straw had 41.9% carbon and 0.4% nitrogen. Before transferring to nylon mesh bag, straw was cut into pieces of 2-3 cm size and 15 g straw sample was filled in nylon mesh (1 x 1 mm, bag of 15 cm x 20 cm size). Bag dimensions permit all straw to be spread in a thin layer within bag thereby ensuring close contact between straw and soil. The bags were placed in soil vertically (15 cm deep) one day after rice transplanting in each plot. All the plots were kept submerged (5-7 cm) from 15[th] day after transplanting until flowering stage of rice crops. At the lapse of 2, 4, 7, 11, 15, 19 and 23[rd] weeks, one nylon mesh bag from each plot was pulled out of the soil, washed with water for removing adhering soil particles and dried in oven at 70±1°C. The remaining straw samples were removed from the bags and weighed and finally ground before subjecting to chemical analysis for carbon and nitrogen by CHN Analyser.

Results and Discussion

Decomposition of wheat straw

The quantity of wheat straw remaining in nylon mesh bag at various sampling intervals is presented in table 1. In general, the wheat straw decomposed faster initially for two weeks and then rate of decomposition slowed down in soil when the assimilable carbohydrates and proteins from residues were exhausted. Henriksen and Breland (1999) reported similar trend of decomposition of crop residues. The warm temperature (minimum 19-27°C and maximum 25-33°C) of rice field during experiment was favourable for straw decomposition. Within 2 weeks, 36.4, 38.2, 39.9, 42.2, 38.6 and 32.6 per cent of the wheat straw had decomposed under treatments namely CR_0Zn_5, $CR_{25}Zn_5$, $CR_{50}Zn_5$, $CR_{100}Zn_5$, $CR_{100}Zn_0$ and CR_0Zn_0, respectively. By the end of 23[rd] weeks, 86.2, 85.5, 87.0, 86.2, 82.3 and 79.4 per cent of wheat straw had decomposed in CR_0Zn_5, $CR_{25}Zn_5$, $CR_{50}Zn_5$, $CR_{100}Zn_5$, $CR_{100}Zn_0$ and CR_0Zn_0 treatments, respectively. This indicated that zinc had accelerated the decomposition of wheat straw from 32.6 to 36.4 per cent at 2 weeks whereas it increased decomposition of wheat straw from 79.4 to 86.2 per cent during entire rice period. Decomposition of wheat straw increased with increasing doses of crop residues. The stimulating effect of zinc on the rate of decomposition of wheat straw may be attributed to utilization of zinc by microbes and crops so it facilitated multiplication of microorganisms to carry out decomposition process. The amount of organic constituents of wheat straw represents a balance between those synthesized and destroyed by microorganisms. Obviously both soluble and insoluble Zn-organic matter complexes are formed and play important role in degradation of straw in soil (Prasad *et al.* 1984; Prasad and Sinha 1995).

Carbon mineralization

Results indicated that the carbon content of wheat straw decreased during first two weeks and beyond this period, the decline in the carbon content of wheat straw continued till end of the experiment. By the end of 23[rd] week, only 24.1, 24.5, 24.7, 25.4, 25.2 and 23.6 per cent carbon remained in the decomposed wheat straw in the treatments namely CR_0Zn_5, $CR_{25}Zn_5$, $CR_{50}Zn_5$, $CR_{100}Zn_5$, $CR_{100}Zn_0$ and CR_0Zn_0, respectively (Table 2). This represented 92.1, 91.7, 92.5, 94.7, 91.6 and 88.1 per cent loss of initial carbon content of wheat straw, respectively (Table 3) account-

Table 1. Decomposition of wheat straw (g) in rice fields

Treatments	Time interval (weeks)						
	2	4	7	11	15	19	23
CR_0Zn_5	9.54 (63.6)	7.43 (49.5)	5.53 (36.8)	4.49 (29.9)	3.09 (20.6)	2.33 (15.5)	2.07 (13.8)
$CR_{25}Zn_5$	9.27 (61.8)	8.07 (53.8)	5.44 (36.2)	4.60 (30.6)	3.59 ()23.9	2.63 (17.5)	2.18 (14.5)
$CR_{50}Zn_5$	9.02 (60.1)	7.80 (52.0)	5.07 (33.8)	4.20 (28.0)	3.27 (21.8)	2.11 (14.0)	1.95 (13.0)
$CR_{100}Zn_5$	8.68 (57.8)	7.28 (48.5)	5.02 (33.4)	4.24 (28.2)	3.42 (22.6)	2.48 (16.5)	2.08 (13.8)
$CR_{100}Zn_0$	9.21 (61.4)	7.57 (50.4)	5.46 (36.4)	4.42 (29.4)	3.91 (26.0)	2.89 (19.2)	2.21 (17.7)
CR_0Zn_0	10.12 (67.4)	8.58 (57.2)	7.10 (47.3)	6.11 (40.7)	5.40 (36.0)	4.12 (27.4)	3.10 (20.6)
CD (P = 0.05)		Treatment (T) = 0.43,		Time (I) = 0.36,		T x I = NS	

Parentheses indicates wheat straw remaining (%)

Table 2. Per cent carbon remained in decomposed wheat straw at different time intervals

Treatments	Time interval (weeks)						
	2	4	7	11	15	19	23
CR_0Zn_5	37.3	35.7	33.3	26.6	25.1	24.5	24.1
$CR_{25}Zn_5$	37.9	36.4	33.9	27.1	25.5	25.0	24.5
$CR_{50}Zn_5$	38.3	36.8	34.3	27.4	25.7	25.2	24.7
$CR_{100}Zn_5$	39.3	37.7	35.2	28.2	26.4	25.9	25.4
$CR_{100}Zn_0$	38.9	37.4	34.8	27.9	26.6	25.7	25.2
CR_0Zn_0	36.4	35.6	32.7	26.1	24.5	24.1	23.6
CD (P = 0.05)		Treatment (T) = 0.56,		Time (I) = 0.48,		T x I = NS	

Table 3. Carbon mineralization (%) of wheat straw

Treatments	Carbon mineralization (%)						
	Time (weeks)						
	2	4	7	11	15	19	23
CR_0Zn_5	43.3	57.8	70.7	81.0	87.7	90.9	92.1
$CR_{25}Zn_5$	45.1	54.2	71.2	79.0	85.7	89.8	91.7
$CR_{50}Zn_5$	46.5	55.5	73.2	80.0	86.9	91.7	92.5
$CR_{100}Zn_5$	48.5	58.6	73.4	82.0	86.4	90.3	94.7
$CR_{100}Zn_0$	45.5	56.9	71.0	81.2	84.1	88.7	91.6
CR_0Zn_0	40.16	51.2	62.2	73.6	78.5	83.9	88.1
CD (P = 0.05)		Treatment (T) = 0.31,		Time (I) = 0.41,		T x I = 1.01	

Table 4. Nitrogen mineralization (%) of wheat straw

Treatments	Nitrogen mineralization (%)						
	Time (weeks)						
	2	4	7	11	15	19	23
CR_0Zn_5	35.6	43.8	54.7	56.1	68.4	76.7	78.0
$CR_{25}Zn_5$	36.9	38.3	54.7	54.8	63.0	73.9	76.1
$CR_{50}Zn_5$	38.6	41.3	58.6	58.7	68.0	76.0	80.0
$CR_{100}Zn_5$	40.7	44.7	57.8	57.9	64.4	75.0	77.6
$CR_{100}Zn_0$	38.6	42.6	56.0	57.3	61.3	72.0	77.3
CR_0Zn_0	31.5	34.2	42.4	42.5	46.5	54.7	67.1
CD (P = 0.05)		Treatment (T) = 0.86,		Time (I) = 0.65,		T x I = 1.58	

ing for 86.2, 85.5, 87.0, 86.2, 82.3 and 79.4 per cent weight loss of wheat straw during the same period and treatment. Effects of treatment, time interval and their interaction on carbon mineralization were significant Carbon mineralization seemed to be the major mechanism of weight loss during decomposition of wheat straw as the pattern of the weight loss of straw and carbon mineralization for the straw is remarkably similar in rice field. This loss includes the loss of other elements associated with carbon and loss of soluble components such as potassium, chloride and certain organic substances produced as intermediate products during decomposition.

Nitrogen mineralization

The N content of wheat straw enhanced considerably during 2^{nd} and 11^{th} week and thereafter little change was noticed. During first two weeks, *i.e.* 35.6, 36.9, 38.6, 40.7, 38.6 and 31.5 per cent of total N in the wheat straw was mineralized in the treatments namely CR_0Zn_5, $CR_{25}Zn_5$, $CR_{50}Zn_5$, $CR_{100}Zn_5$, $CR_{100}Zn_0$ and CR_0Zn_0, respectively (Table 4). There was change in the trend of N mineralization between 3^{rd} week and 7^{th} week and between 8^{th} week and 23^{rd} week. Christensen (1985) also noticed a similar trend of N content of the wheat straw during its decomposition. Immobilization of inorganic N during decomposition of wheat straw in soil is expected due to its wide C/N ratio (0.87) and nitrogen immobilization caused by wheat straw incorporation is considered responsible for the adverse effects on rice yield in rice-wheat system (Beri *et al.* 1995; Mishra *et al.* 2001; Sriniwas *et al.* 2006). After 11^{th} week, however, net N mineralization again commenced and then it followed almost a linear course upto 23^{rd} week. Apparently 78.0, 76.1, 80.0, 77.6, 77.3 and 67.1 per cent of total N in the wheat straw was mineralized by the end of 23^{rd} week in the treatments *i.e.* CR_0Zn_5, $CR_{25}Zn_5$, $CR_{50}Zn_5$, $CR_{100}Zn_5$, $CR_{100}Zn_0$ and CR_0Zn_0, respectively (Table 4). It was further observed that N mineralization from the wheat straw was slower than carbon mineralization. It seems that zinc had stimulated mineralization of carbon as well as nitrogen. As a result of carbon mineralization, the C/N ratio of remaining wheat straw narrowed down from 85.5:1 to 30.1:1, 87.1:1 to 30.2:1, 86.2:1 to 30.1:1 to 86.6:1 to 30.6:1, 87.6:1 to 31.1:1 and 83.7:1 to 29.9:1 in the treatments of CR_0Zn_5, $CR_{25}Zn_5$, $CR_{50}Zn_5$, $CR_{100}Zn_5$, $CR_{100}Zn_0$ and CR_0Zn_0, respectively.

The present study indicates that the decomposition of wheat straw in rice-grown calcareous soils was almost completed in 23^{rd} week. The C/N ratio of wheat straw was not much affected by zinc and different levels of crop residue application at end of 23^{rd} weeks of mineralization.

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