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Comparative Effects of Crop Residue and Nutrient Combination on Soil Total Nitrogen Dynamics at Different Stages of Crop Growth under Maize-Wheat Cropping System

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ABSTRACT

A 2-year field experiment was conducted over 4 growing seasons from 2016 to 2018 in farm area of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Ranchi, Jharkhand, during *Kharif* and *Rabi* season to assess the effects of crop residue incorporation on soil total nitrogen dynamics at different stages of crop growth under maize-wheat cropping system. There were 5 treatments each replicated four times. The experiment was laid out in Randomized Block Design. The result showed that application of N, P and K either alone or in combination with crop residue recorded significantly higher total N content over nutrient omission plots and total N was increased progressively with NPK + crop residue treatment over residue removal. The incorporation of crop residues significantly increased soil total N content with advancement of crop upto V_{10} stage which varied from 0.066 - 0.098 per cent while the lowest total N was reported at after harvest varied from 0.034-0.050 per cent in maize crop. The lowest soil total nitrogen content was recorded in N omitted plot *viz.*, 0.025 and 0.024 per cent with and without residue, respectively in wheat crop. Total N content of the soil at lower depth decreased with the depth (15-30 cm) varied from (0.022 - 0.090 per cent) and (0.015 - 0.071 per cent) with and without incorporation of wheat straw, respectively in maize crop.

Introduction

The world population is projected to be reach 9.7 billion by 2050 (UN, Dept of Economics and Social Affairs, 2015) which means in future greater demand for grain production. However, the limited cultivable land and stagnant crop yields production have made the task more challenging (Tilman *et al.*, 2002). Consequently, intensive farming systems with short fallow periods and high fertilizer inputs have been used to achieve higher crop yields. Chemical fertilizers provide nutrients in readily available form, but its continuous use in a same piece of land deteriorates the soil health and ultimately reduces the grain production. Maize-wheat is the third most important cropping system in India and second most in Jharkhand. Both the crops are fertilizer responsive and exhibit full yield potential when supplied with adequate quantities of nutrients at proper time. But poor economic resources of the Jharkhand farmers compel to go for imbalance fertilizer use leading to deterioration of soil fertility and crop productivity.

Nitrogen is an essential plant nutrient and available to the plant mainly in the NH_4^+ (ammonium) and NO_3^- (nitrate) forms. In the soil, it is present in many other complex forms which are broken down to NH_4^+ and NO_3^- ions by soil microbial activities. Nitrogen is of special importance because plants need it in rather large amounts, it is fairly expensive to supply, and it is easily lost from the soil. The total nitrogen content of the soil is an important property to measure as part of the characterization of soil nitrogen. The determination of total nitrogen (TN) content in soil including that present as both chemically stable humus (or passive) and partially decomposed plant and animal residues (or active) organic matter fractions. The determination of soil total nitrogen content gives some indication of the N supplying power of a soil, but it's primary use is to enable the expression of other, related parameters (Organic C) relative to this property. Total N can be the N status of a soil, but side by side potentially mineralizable nitrogen (PMN) which is a fraction of organic N should be considered as a soil quality indicator. Because this will be available during the crop growing season. Therefore it is acceptable to use soil total nitrogen as soil quality indicator for overall assessment of fertility status A major factor in successful farming is the farmer's ability to manage nitrogen efficiently. Many measures have been taken to improve soil fertility and productivity. The most effective measure is increasing the organic input, such as with the application of organic residues as straw incorporation (Wei *et al.,* 2015; Zhang *et al.,* 2016). Crop straw, an easy-to-get, nutrient-rich resource, has great value for improving soil fertility (Tan *et al.,* 2017).

Many studies have reported that crop straw is rich in nutrients and organic materials, can be treated as a natural organic fertilizer, and used as an alternative to chemical fertilizers (Bakht *et al.,* 2009; Wang *et al.,* 2017). Crop residues bearing about 25 % of N & P, 50 % of S and 75 % of K uptake by cereal crops are retained in crop residues (Singh *et al.,* 2018; Xu *et al.,* 2010). The incorporation of crop residues has been proven as an effective sources in terms of reducing nutrient inputs (Ma *et al.,* 2003), especially potassic and nitrogenous fertilizers. Therefore straw incorporation seems promising to maintain and restore soil fertility. The studies cited above have investigated the effects of crop residue incorporation on soil total nitrogen dynamics at different stages of crop growth under maize-wheat cropping system.

Materials and Methods

A 2-year field experiment was conducted over 4 growing seasons from 2016 to 2018 in farm area of Soil Science and Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi, Jharkhand, during *Kharif* and *Rabi* season. The experimental area comes under Agro-climatic Zone V, situated at latitude of $23^0 19^{'}$N and longitude $83^0 17^{'}$E with an altitude of 625 metre above MSL and the climate of this region is subtropical with hot and dry summer, comparatively cool in rainy season fallowed by moderate winter. The region receives rainfall from both the streams of monsoon *i.e.* South–West monsoon and North–East monsoon. The weekly average maximum temperature varied from 27.9 to 37.7^0C and 25.9 to 34.4^0C, respectively, in the years 2016 and 2017 for maize crop, while, it varied from 22.9 to 40.5^{0}C and 20.0 to 35.2^{0}C, respectively, in the years 2016-17 and 2017-18 for wheat crop. The variation in weekly average minimum was from 20.3 to 24.9^{0}C and 16.6 to 22.6^{0}C, respectively, in the years 2016 and 2017 for maize, whereas, it varied from 3.5 to 22.0^{0}C and 2.0 to 19.7^{0}C, respectively, in the years 2016-17 and 2017-18. There was about 1276 mm and 1602 mm rainfall, respectively, during 2016-17 and 2017-18 in 47th weeks. Each plot was divided into two equal parts before sowing of crops. In one part, straw (maize/wheat) (which was obtained from that plot during last crop) was incorporated along with chemical fertilizer and in another part, only chemical fertilizer was applied as per treatments. Altogether there were comprising five treatments with and without crop residues incorporation, replicated four times in a Randomized Block Design to give a total of 40 experimental units. The experiment consisted of five treatments including: T1 - ample NPK (250: 120: 120 kg/ha), T2 - omission of N (-N), T3 - omission of P (-P), T4 - omission of K (-K) & T5 - SSNM (200: 90: 100 NPK kg/ha) for maize in kharif season. The corresponding treatments for wheat in rabi season were (T1= NPK) 150: 110: 100 kg/ha, (T2 = -N) (T3 = -P) (T4 = -K) and (T5 = SSNM) 120: 70: 60 NPK kg/ha. The sources of N, P, and K were urea, single super phosphate and muriate of potash, respectively. Soil samples from the plots of each treatments and replication were collected at depth 0-15 and 15-30 cm.

The soil samples were collected at different stages i.e. at V_4 (four leaves) stage, V_{10} (ten leaves) stage and after harvest of the maize crop (during maize crop season) and at CRI (Crown root initiation), PI (Panicle initiation) and after harvest of wheat (during wheat Crop season). Samples were brought to the laboratory, air-dried in the shade and grounded by wooden roller, thereafter sieved through 2 mm stainless steel sieve and stored in polythene bags and used for chemical assay.

Total nitrogen is estimated by the micro-Kjeldahl method as per procedure suggested by AOAC (1995). Nitrogen in soil samples exists in a very complicated bonding structure. During digestion, a known weight of the soil samples in the presence of sulphuric acid with catalyst mixture under high temperature is digested where complicated structures are broken to simple structure, thereby releasing nitrogen in the form of ammonium radical (NH_4^+).

During distillation in presence of sodium hydroxide, the released ammonia is condensed and absorbed in known volume of a boric acid with mix indicator to form ammonium borate, the excess of which is titrated with a standard sulphuric acid.

The micro-Kjeldahl method consists of the three steps;

Digestion

Distillation and

Titration.

For estimation of soil total nitrogen weight 0.2 g soil sample in test tube and digested in test tube with 1g mixture ($CuSO_4$: K_2SO_4: selenium powder in the ratio of 10:50:1) and 5 ml H_2SO_4.

Digested soils were distilled in distillation flask containing 40 ml of 40% NaOH solution. Liberated Ammonia gas was absorbed in 500 ml conical flask containing 20 ml of 4 percent Boric acid plus few drops of mixed indicator. Distillate was titrated against N/10 H_2SO_4.

Calculations :

Nitrogen content in soil (%) =

$$\frac{\text{R (sample titer - blank titer) x Normality of acid } (H_2SO_4) \text{ x Atomic weight of nitrogen x 100}}{\text{Sample weight (g) x 1000}}$$

Results and Discussion

Maize

Effect of crop residues

A perusal of pooled data (Table 1) showed that the effect of crop residue on soil total nitrogen. The results revealed that the incorporation of crop residue recorded 14.29 and 33.33 per cent significantly higher concentration of soil total nitrogen as compared to without incorporation of crop residues, i.e., 0.072 and 0.031 (%) at V_4 and after harvest stage, respectively. While, at V_{10} stage there was no significant change was reported by addition of crop residue. However, at 15-30 cm depth of soil this increment was noted as 16.67, 33.33 and 50.00 per cent significantly higher soil total nitrogen over without crop residue, i.e., 0.057, 0.062 and 0.024 (%) (Table 2). The maximum soil total nitrogen status was recorded at V_{10} stage of maize crop. The soil total N content was decreased with increasing soil depth it might be due to low C sequestration in the soil **(**Witt *et al.,* 2000).

Effect of Nutrient combination:

The data presented in (Table 1 & 2) showed that the effect of nutrient application on soil total nitrogen content. The higher content of soil total nitrogen was recorded under NPK in all growth stages e.g., 100.00, 50.00 and 2.00 per cent in surface soil and in sub-surface soil 40.00, 2.00 and 2.00 per cent significantly higher soil total nitrogen compared to minimum observed under N omitted plot i.e., 0.048, 0.060 & 0.024 (%) and 0.052, 0.058 & 0.018 (%) at V_4, V_{10} and after harvest stage, respectively.

Interaction effect of crop residues and nutrient combination

Soil total N is reservoir of available N. Total N content of the soil at different stages during kharif (maize crop) varied from 0.026 - 0.098 per cent with incorporation of residues, while, without residue incorporation it varied from 0.022 – 0.095 per cent (Table-1.1). Total N content of the treated soil increased with advancement of crop upto V_{10} stage which varied from 0.066 - 0.098 per cent while the lowest total N was reported at after harvest varied from 0.034-0.050 per cent. Total N at harvest showed a decrease, which may be due to higher uptake of N by plants for their proper growth and development. Increase in total N with crop residue incorporation may be attributed to the positive balance of total soil organic carbon (SOC) and also due to slow mineralization of added crop residue which resulted the higher value of total N at stage V_{10}. Similar, findings was also reported by, Shafi *et al.,* (2010), who reported that post-harvest incorporation of crop residues on soil had significantly increased soil total N. The reason for the reduction in total soil N due to residues incorporation during initial stage of crop growth, might be due to the immobilization of nitrogen after incorporation of stover in the soil and also to their high C: N ratio (Shafi *et al.,* 2010). The data (Table 1.1) showed that the interaction, crop residues and nutrient combination did not have significant effect on soil total nitrogen.

Total N content of the soil at lower depth decreased with the depth (15-30 cm) varied from (0.022 - 0.090 per cent) and (0.015 -

0.071 per cent) with and without incorporation of wheat straw, respectively (Table-2.1). However, total N was highest at stage V_{10}. The results clearly showed that the addition of organic wastes with mineral N could increase the total N content of the soil. These findings are in agreement with those of Kushwaha *et al.*, (2000), Anwar *et al.*, (2005) and Bhattacharya *et al.*, (2008). The data (Table 2.1) exhibit that a significant interaction effect among crop residues and nutrient combination at V_4 stage of crop growth.

Wheat

Effect of crop residues

Table 3 & 4 showed the effect of crop residue on soil total nitrogen status, and revealed that the incorporation of crop residue recorded 50.00 per cent significantly higher soil total nitrogen compared to complete removal of crop residues treatments, i.e., 0.043 (%) at CRI stage of wheat crop, however, at PI and after harvest there was no significant changes were reported. Similarly, at 15-30 cm depth of soil the incorporation of crop residue recorded 33.33 and 50.00 per cent significantly higher soil total nitrogen as compared to no crop residue incorporation i.e., 0.034 and 0.023 (%) at PI and after harvest respectively.

Effect of nutrient combination

The data presented in Table (3 & 4) showed that the highest total nitrogen in surface soil was recorded under NPK in all crop growth stages, which were 50.00, 66.67 and 100.00 per cent higher compared to minimum observed under N omission, i.e., 0.035, 0.030 and 0.024 %, at CRI, PI and after harvest stage of wheat crop, respectively

Table.1 Soil Total Nitrogen (%) (0-15 cm) as influenced by crop residue and nutrient combination (maize) (pooled of 2 yrs.)

Treatments	Crop Stages		
	V_4	V_{10}	After Harvest
Crop residue (CR)			
With CR	0.081	0.080	0.038
Without CR	0.072	0.076	0.031
SEm ±	0.002	0.001	0.001
CD (p=0.05%)	0.006	0.004	0.004
Nutrient Combination			
NPK	0.095	0.093	0.044
N omission (-N)	0.048	0.060	0.024
P omission (-P)	0.081	0.076	0.031
K omission (-K)	0.068	0.074	0.032
SSNM	0.089	0.086	0.040
SEm ±	0.003	0.002	0.002
CD (p=0.05%)	0.009	0.006	0.006
Interaction (CR x N)			
SEm ±	0.004	0.003	0.003
CD (p=0.05%)	NS	NS	NS
CV%	16.62	11.16	25.33

Table.1.1 Soil Total Nitrogen (%) (0-15 cm) as influenced by interaction effect of crop residue and nutrient combination (maize) (pooled of 2 yrs.)

Treatments	V_4		V_{10}		After Harvest	
	Without CR	With CR	Without CR	With CR	Without CR	With CR
NPK	0.095	0.096	0.089	0.098	0.039	0.050
N omission (-N)	0.040	0.055	0.054	0.066	0.022	0.026
P omission (-P)	0.076	0.086	0.076	0.075	0.028	0.034
K omission (-K)	0.060	0.076	0.073	0.075	0.031	0.034
SSNM	0.087	0.090	0.086	0.085	0.034	0.046
SEm ±	0.004		0.003		0.003	
CD (p=0.05%)	NS		NS		NS	

Table.2 Soil Total Nitrogen (%) (15-30 cm) as influenced by crop residue and nutrient combination (maize) (pooled of 2 yrs.)

Treatments	Crop Stages		
	V_4	V_{10}	After Harvest
Crop residue (CR)			
With CR	0.072	0.075	0.029
Without CR	0.057	0.062	0.024
SEm ±	0.002	0.001	0.001
CD (p=0.05%)	0.004	0.004	0.004
Nutrient Combination			
NPK	0.068	0.080	0.035
N omission (-N)	0.052	0.058	0.018
P omission (-P)	0.068	0.063	0.021
K omission (-K)	0.064	0.067	0.025
SSNM	0.071	0.076	0.032
SEm ±	0.002	0.002	0.002
CD (0.05%)	0.007	0.006	0.006
Interaction (CR x N)			
SEm ±	0.003	0.003	0.003
CD (p=0.05%)	0.07	NS	NS
CV%	15.02	13.24	33.55

Table.2.1 Soil Total Nitrogen (%) (15-30 cm) as influenced by interaction effect of crop residue and nutrient combination (maize) (pooled of 2 yrs.)

Treatments	V_4		V_{10}		After Harvest	
	Without CR	With CR	Without CR	With CR	Without CR	With CR
NPK	0.052	0.083	0.070	0.090	0.035	0.036
N omission (-N)	0.050	0.054	0.055	0.061	0.015	0.022
P omission (-P)	0.059	0.077	0.057	0.069	0.018	0.025
K omission (-K)	0.061	0.068	0.058	0.075	0.021	0.028
SSNM	0.061	0.080	0.071	0.082	0.030	0.033
SEm ±	0.003		0.003		0.003	
CD (0.05%)	0.07		NS		NS	

Table.3 Soil Total Nitrogen (0-15 cm) as influenced by crop residue and nutrient combination (Wheat) (pooled of 2 yrs.)

Treatments	Crop Stages		
	CRI	PI	After Harvest
Crop residue (CR)			
With CR	0.0603	0.044	0.031
Without CR	.0398	0.043	0.030
SEm ±	0.002	0.001	0.001
CD (p=0.05%)	0.004	0.003	0.002
Nutrient Combination			
NPK	0.064	0.054	0.036
N omission (-N)	0.035	0.030	0.024
P omission (-P)	0.045	0.042	0.028
K omission (-K)	0.049	0.045	0.032
SSNM	0.057	0.047	0.033
SEm ±	0.002	0.002	0.001
CD (p=0.05%)	0.007	0.004	0.004
Interaction (CR x N)			
SEm ±	0.004	0.002	0.002
CD (p=0.05%)	NS	0.01	NS
CV%	19.94	14.49	16.75

Table.3.1 Soil Total Nitrogen (0-15 cm) as influenced by interaction effect of crop residue and nutrient combination (Wheat) (pooled of 2 yrs.)

Treatments	CRI		PI		After Harvest	
	Without CR	With CR	Without CR	With CR	Without CR	With CR
NPK	0.053	0.075	0.051	0.056	0.034	0.038
N omission (-N)	0.025	0.045	0.035	0.025	0.024	0.025
P omission (-P)	0.038	0.053	0.040	0.044	0.026	0.029
K omission (-K)	0.038	0.061	0.044	0.046	0.033	0.031
SSNM	0.046	0.068	0.046	0.049	0.031	0.034
SEm ±	0.004		0.002		0.002	
CD (p=0.05%)	NS		0.01		NS	

Table.4 Soil Total Nitrogen (15-30 cm) as influenced by crop residue and nutrient combination (Wheat) (pooled of 2 yrs.)

Treatments	Crop Stages		
	CRI	PI	After Harvest
Crop residue (CR)			
With CR	0.040	0.039	0.026
Without CR	0.035	0.034	0.023
SEm ±	0.001	0.001	0.001
CD (p=0.05%)	0.004	0.003	0.002
Nutrient Combination			
NPK	0.047	0.045	0.029
N omission (-N)	0.027	0.021	0.019
P omission (-P)	0.035	0.032	0.023
K omission (-K)	0.035	0.041	0.024
SSNM	0.045	0.044	0.026
SEm ±	0.002	0.001	0.001
CD (p=0.05%)	0.006	0.004	0.003
Interaction (CR x N)			
SEm ±	0.003	0.002	0.002
CD (p=0.05%)	NS	NS	NS
CV%	20.90	15.86	19.36

Table.4.1 Soil Total Nitrogen (15-30 cm) as influenced by interaction effect of crop residue and nutrient combination (Wheat) (pooled of 2 yrs.)

Treatments	CRI		PI		After Harvest	
	Without CR	With CR	Without CR	With CR	Without CR	With CR
NPK	0.044	0.050	0.041	0.049	0.028	0.030
N omission (-N)	0.025	0.029	0.020	0.021	0.018	0.020
P omission (-P)	0.034	0.036	0.031	0.033	0.023	0.024
K omission (-K)	0.033	0.038	0.038	0.044	0.023	0.026
SSNM	0.041	0.049	0.039	0.049	0.024	0.028
SEm ±	0.003		0.002		0.002	
CD (p=0.05%)	NS		NS		NS	

Similarly, at 15-30 cm depth of soil the highest soil total nitrogen was also recorded under same treatment NPK which were observed 66.67, 150.00 and 50.00 per cent significantly higher as compared to minimum observed under N omission, i.e., 0.027, 0.021 and 0.019 (%) at CRI, PI and after harvest, respectively.

Interaction effect of crop residues and nutrient combination

It was evident from the Table-3.1 that the total N content at different stage of wheat growth during winter season ranged from 0.025 - 0.075 per cent and 0.024 – 0.053 per cent with and without crop residue incorporation. Application of N, P and K either alone or in combination with crop residue recorded significantly higher total N content over nutrient omission plots and total N was increased progressively with NPK + crop residue treatment over residue removal. It decreased at Panicle initiation stage, but the interaction, among crop residues and nutrient combination showed a significant and positive effect on soil total nitrogen. The lowest content was recorded in N omitted plot (0.025 and 0.024 per cent with and without residue, respectively) at after harvest stage, which may be due to slow decomposition rate of maize straw compared to that of wheat straw. Similar results were reported earlier by Reiter *et al.*, (2002). The data (Table 3.1) exhibit that a significant interaction effect among crop residues and nutrient combination at PI stage of crop growth and highest soil total nitrogen was recorded under NPK which was 100.00 per cent significantly higher as compared to minimum observed under N omission treatment.

At lower depth (15-30 cm) the value of total N content varied from 0.020 - 0.050 and 0.018 - 0.044 per cent with and without incorporation of crop residues, respectively (Table-4.1). The interaction, among crop residues and nutrient combination did not show significant effect on soil total N content. The results clearly showed that the addition of organic wastes with mineral N could increase the total N content of the soil (Kushwaha *et al.*, 2017). Total N at harvest showed a decreasing trend, which may be due to higher uptake of N by plants. It was observed that the value of total N content decreased with the depth. These findings are in agreement with Rezig *et al.*, (2012). The data (Table 4.1) showed that the interaction, crop residues and nutrient combination did not have significant effect on soil total nitrogen.

In conclusion, the application of N, P and K either alone or in combination with crop residue recorded significantly higher total N content over nutrient omission plots and total N was increased progressively with NPK + crop residue treatment over residue removal. Total N content of the soil at lower depth decreased with the depth (15-30 cm).

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