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Influence of crop residue incorporation in maize crop on yield, agronomic efficiency and partial factor productivity in acid soil of Ranchi

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Abstract
Crop residues are parts of the plants left in the field after crops have been harvested and threshed. In India there are 500-550 million tonnes (Mt) of crop residues are produces annually. Crop residue incorporation provides the essential nutrients in the soil after its decomposition. Keeping in view of the importance of crop residue, a field experiment was conducted in kharif 2016 on hybrid maize (*var*. Pioneer – 3377) comprising five treatments with and without crop residue incorporation along with chemical fertilizers, *viz*. NPK (250:120:120 kgha^{-1}), N_0PK (0:120:120 kgha^{-1}), NP_0K (250:0:120 kgha^{-1}), NPK_0 (250:120:0 kgha^{-1}) and SSNM (200: 120: 120 kgha^{-1}) with the objective to determine the response of several fertilizers with crop residue application to maize production and to evaluate their agronomic efficiency (AE) and partial factor productivity (PFP). Results showed that balanced dose of fertilizers application gave highest agronomic efficiency (AE) of applied N, P & K (28.28 and 27.05, 15.90 and 13.08 & 32.25 and 33.03 kg grain kg^{-1}) followed by SSNM (29.30 and 27.77, 7.75 and 4.01 & 26.60 and 27.55 kg grain kg^{-1}) in both the situation: with and without crop residues incorporated plots respectively. Minimum agronomic efficiency obtained when improper dose of Chemical fertilizer applied. Maximum partial factor productivity of applied N, P & K under SSNM treatment (37.70 and 35.70, 83.90 and 79.40 & 75.50 and 71.50 kg grain yield kg^{-1}N, P & K applied respectively) followed by NPK treatment (35.00 and 33.40, 73.00 and 69.60 & 73.00 and 69. 00 kg grain yield kg^{-1}N, P & K applied respectively) in with and without incorporation of crop residues. Whenever agronomic efficiency and partial factor productivity (PFP) was compared with incorporation of crop residues and without incorporation of crop residues, then both (AE and PFP) were more in crop residues incorporated plots than without incorporation of crop residues.

Keywords: Crop residue, maize (*Zea mays* L.), agronomic efficiency, partial factor productivity

Introduction
Maize (*Zea mays* L.) is an important staple food grain crop of the world next to wheat and rice. The importance of maize lies in its wide industrial uses besides serving a food and fodder. It is the most versatile crop with wider adaptability to varied agro ecological regions, zones and has the highest genetic yield potential among the food grain crops grown. Since the demand for the maize is increasing globally due to its multiple uses, there is a need to enhance its productivity from same or even less available resources. Maize is cultivated both in temperate and tropical regions of the world. It is cultivated on nearly 150 mha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36% (782 mt) in the global grain production. The USA has the highest productivity (9.6 t ha^{-1}) which is double than global average (4.92 t ha^{-1}). The Ministry of New and Renewable energy (MNRE, 2009) Govt. Of India has estimated that about 500 Mt of crop residues are generated every year. Cereal crops (rice, wheat, maize, millets) contribute 70% of crop residues. Incorporation of crop residues into soil or retention on the surface has several positive influences on chemical properties and agronomical parameter of soil. Continuous addition of crop residue increases organic matter status of soil. Crop residue favour carbon sequestration in soils (Behera, 2018) [1].

Partial factor productivity (PFP) and agronomic efficiency is a useful measure of nutrient use efficiency as it provides an integrative that quantifies total economic output relative to the utilization of all nutrient resources in the system (Yadav, 2003) [8].

Materials and Methods

The present investigation was conducted on the Research Farm of the Department of the Soil Science & Agricultural Chemistry, BAU, Ranchi. The experimental plot comes under Agro climatic Zone V (situated at $23^0$19' N and $83^0$17') and has an altitude of 625 meter above MSL (mean sea level). Field experiments were initiated in the year 2009 under an IPNI (India Programme) sponsored Programme on Nutrient Omission Plot studies to study the relative assessment of the soil on its inherent nutrient supplying capacity. During 2011-12, the experiment was modified to evaluate the effect of crop residue incorporation on crop productivity and nutrient use efficiency of maize. The total rainfall received by the area during 2016-2017 was 1265.2 mm with peak period of rainfall from June to September. The relative humidity varied from about 27 percent in March to 75 percent in January 2017 recorded at 2 PM. The experimental design was laid out in factorial Randomized Block Design comprising ten treatments (including five crop residue treatment and five without crop residue treatment) such as T_1 – full dose of NPK + CR (250:120:120 Kgha^{-1}), T_2- omission of N with full dose of P and K + CR (-N= 0:120:120 NPK Kgha^{-1}), T3- omission of P with full dose of N and K +CR (-P= 250:0:120 NPK Kgha^{-1}), T4- omission of K with full dose of N and P + CR(-K= 250:120:0 NPK Kgha^{-1}) & T_5- SSNM (200:90:100 NPK Kgha^{-1}). Same trend follows without crop residue incorporated treated plot. The maize variety Pioneer-3377 was used during the present investigation. The soil samples were collected at depth of 0-15 cm. The amount of crop residue (wheat straw) N, P & K added with NPK treated plot was T_1 (NPK + CR); 250 + 26.72: 120 + 10.69: 120 + 53.44 Kgha^{-1}, T_2 (N_0PK + CR); 0 + 7.52: 120 + 3.01: 120 + 15.03 Kgha^{-1}, T_3 (NP_0K + CR); 250 +17.70: 0 + 7.08: 120 + 35.40 Kgha^{-1}, T4 (NPK_0 + CR); 250 + 26.95: 120 + 10.78: 0 + 53.90 Kgha^{-1} and T_5 - SSNM (NPK + CR); 200 + 29.66: 90 + 11.86: 100 + 59.32 Kgha^{-1}. Wheat straw was chopped and incorporated in the plot. After one month maize was sown.

Agronomic Efficiency

Agronomic efficiency of applied N, P and K were computed by using the expression:

$$\frac{\text{Agronomic efficiency of applied N (Kgha}^{-1}\text{)}}{\text{(Kg grain yield increase per Kg nutrient applied)}} = \frac{GY_N - GY_0}{FN}$$

Where

GY_N = Grain yield in N applied plot

GY_0 = Grain yield in (-N) applied plot FN = Fertilizer N applied in Kgha^{-1} Similarly, agronomic efficiency of P and K were calculated.

Partial Factor Productivity

Partial factor productivity of applied N, P and K were computed by using the expression:

$$\text{Partial factor productivity of applied nutrient (N) (Kg grain yield per Kg nutrient N applied) (Kgha}^{-1}\text{)} = \frac{GY_N \text{ (grain yield in a treatment with N application)}}{\text{FN (amount of fertilizer N applied in}}$$

Similarly, Partial factor productivity of applied P and K were calculated.

Results and Discussion

Crop residue incorporated soil likely to bring about changes in the availability and transformation of essential plant nutrients, which ultimately affect the agronomic efficiency and partial factor productivity of applied N, P and K. Among the overall treatments crop residue incorporated plot gave higher agronomic efficiency and partial factor productivity than without crop residue incorporated plots.

Effect of crop residue incorporation on Yield

The maize grain and straw yield was significantly affected by due to addition of crop residue (Table 1). The maximum yield (grain and straw) was observed in NPK (85.66 qha^{-1} & 112.81 qha^{-1} respectively) treated plot, when heavy dose of N, P_2O_5 & K_2O (250 kg N, 120 kg P_2O_5 and 120 kg K_2O per hectare) was added continuously. In NPK treated plot this yield was significantly higher than SSNM (grain yield 73.61 qha^{-1} & straw yield 98.90 qha^{-1}), NP_0K (grain yield 68.27 qha^{-1} & straw yield 93.22 qha^{-1}), NPK_0 (grain yield 47.11 qha^{-1} & straw yield 64.87 qha^{-1}) and N_0PK (grain yield 16.49 qha^{-1}& straw yield 30.92 qha^{-1}). The yield obtained in SSNM treatment was significantly lower than that of NPK treatment. This might be due to the level of nutrient supplied to SSNM treatment (N, P_2O_5 & K_2O kgha^{-1} is 200 kg N, 90 kg P_2O_5 & 100 kg K_2O) was less than that of NPK (250: 120: 120 kgha^{-1} N, P_2O_5 & K_2O) treatment. It was also observed that yield of NP_0K was significantly lower than NPK and SSNM treated plot. This might be due to the absence of phosphatic fertilizer. It was also observed that lower yield obtained in N_0PK (grain yield 16.49 qha^{-1} & straw yield 30.92 qha^{-1}) treated plot which was significantly lower than other treatment. This might be due to the absence of nitrogenous fertilizer. Crop residue incorporated soil increased the straw yield in comparison of residue removed treatments. Similarly, Shafi *et al.* (2007) [4] and Bakht *et al.* (2009) [2] reported that shoot biomass was increased with residues retention.

Agronomic Efficiency

The agronomic efficiency of nutrient N, P & K (AEN, AEP & AEK) increase in yield per unit of N, P & K applied, was used as the measure of the efficiency of nutrient N, P & K uses respectively. The grain yield was increased due to the application of nutrient N, P & K which is the difference between the target yield and yield without nutrient N, P & K. Agronomic efficiency of applied K was higher (32.25 and 33.03 kg increase in grain yield per kg applied K) than agronomic efficiency of applied N (28.28 and 27.05 kg increase in grain yield per kg applied N) and agronomic efficiency of P (15.90 and 13.08 kg increase in grain yield per kg applied P) in with and without crop residue incorporated plot. Higher agronomic efficiency of potassium due to the continuous addition of crop residue (since crop residue contain nearly to 75% to 80% potassium) (Singh *et al*., 2018). Improved crop residue and organic waste management aids in avoiding K depletion (Bijay-Singh *et al.*, 2004; Oborn *et al.*, 2005). Furthermore, crop K requirements could be improved by retention of crop residue (Yadvinder-Singh *et al.*, 2010; Singh *et al*., 2018) [7, 6] further improving KUE.

Partial factor productivity

Partial-factor productivity is the ratio of total output to a single input. Partial factor productivity of applied nutrient is measured in kg grain yield per kg nitrogen applied. Partial factor productivity of applied nitrogen was 35 and 33.4 kg grain yield per kg nitrogen applied in with and without crop residue incorporated plot. Partial factor productivity of applied P & K (73 kg grain yield per kg P & K applied for both) was maximum in crop residue incorporated plot than without crop residue incorporated plot (69.6 kg grain yield per kg P & K applied for both). Partial factor productivity of applied N, P & K under SSNM treatment (37.70 and 35.70, 83.90 and 79.40 & 75.50 and 71.50 kg grain yield per kg N, P & K applied respectively) was higher than that of NPK treatment (35.00 and 33.40, 73.00 and 69.60 & 73.00 and 69.60 kg grain yield per kg N, P & K applied respectively) in with and without crop residue incorporated plot.

Table 1: Effect of wheat crop residue incorporation on hybrid maize yield (qha^{-1})

Treatments		Grain yield			Straw yield		
		CR	CR_0	Mean	CR	CR_0	Mean
NPK		87.69	83.63	85.66	113.9	111.72	112.81
N_0PK		16.98	16.00	16.49	31.63	30.21	30.92
NP_0K		68.61	67.93	68.27	93.25	94.10	93.22
NPK_0		48.99	43.99	47.11	67.15	62.55	64.87
SSNM		75.59	71.54	73.61	99.22	98.58	98.90
Mean value		59.57	56.89		80.85	79.44	
CD (0.05)	Factor A	8.11			11.29		
	Factor B	NS			NS		
	F (AXB)	NS			NS		
CV (%)		6.75%			6.83%		
SE (m)	Factor A	2.78			3.87		
	Factor B	1.76			2.44		
	F (AXB)	3.93			5.47		

Table 2: Agronomic efficiency of Nutrients as influenced by wheat crop residue incorporation and nutrient use in hybrid maize crop (kg grain kg^{-1} nutrient)

Parameters	CR	CR_0
Agronomic efficiency of applied N (NPK)	28.28	27.05
Agronomic efficiency of applied P (NPK)	15.90	13.08
Agronomic efficiency of applied K (NPK)	32.25	33.03
Agronomic efficiency of applied N (N_0PK)	----------	---------
Agronomic efficiency of applied P (N_0PK)	-43.02	-43.27
Agronomic efficiency of applied K (N_0PK)	-26.67	-23.32
Agronomic efficiency of applied N (NP_0K)	20.65	20.77
Agronomic efficiency of applied P (NP_0K)	-------	-----------
Agronomic efficiency of applied K (NP_0K)	16.35	19.95
Agronomic efficiency of applied N (NPK_0)	12.80	11.19
Agronomic efficiency of applied P (NPK_0)	-16.35	-19.95
Agronomic efficiency of applied K(NPK_0)	-------	-------
Agronomic efficiency of applied N (SSNM)	29.30	27.77
Agronomic efficiency of applied P(SSNM)	7.75	4.01
Agronomic efficiency of applied K (SSNM)	26.60	27.55

Table 3: Effect of wheat crop residue incorporation on partial factor productivity (kg grain kg^{-1} nutrient) of applied N, P, and K with NPK and SSNM treatment

Parameters	CR	CR_0
Partial Factor Productivity of applied N (NPK)	35.00	33.4
Partial Factor Productivity of applied P (NPK)	73.0	69.6
Partial Factor Productivity of applied K (NPK)	73.0	69.6
Partial Factor Productivity of applied N (N_0PK)	--------	---------
Partial Factor Productivity of applied P (N_0PK)	14.1	13.3
Partial Factor Productivity of applied K (N_0PK)	14.1	13.3
Partial Factor Productivity of applied N (NP_0K)	27.40	27.1
Partial Factor Productivity of applied P (NP_0K)	--------	-------
Partial Factor Productivity of applied K (NP_0K)	57.1	56.6
Partial Factor Productivity of applied N (NPK_0)	19.50	17.5
Partial Factor Productivity of applied P(NPK_0)	40.8	36.6
Partial Factor Productivity of applied K(NPK_0)	--------	-------
Partial Factor Productivity of applied N(SSNM)	37.70	35.7
Partial Factor Productivity of applied P(SSNM)	83.9	79.4
Partial Factor Productivity of applied K(SSNM)	75.5	71.5

Conclusions

Among overall treatments, crop residue incorporated soil shows higher agronomic efficiency and partial factor productivity than without crop residue incorporated plot. Crop residue incorporated soil got higher yield (grain yield 59.57 qha^{-1} & straw yield 80.85 qha^{-1}) than without crop residue incorporated soil.

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