Current Journal of Applied Science and Technology

37(6): 1-6, 2019; Article no.CJAST.52050
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Effect of Crop Residues Management on Soil Properties and Crop Productivity of Rice-wheat System in *Inceptisols* of *Seemanchal* Region of Bihar

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2019/v37i630324
Reviewers and Editors: This manuscript was reviewed and approved by ICCRM-2019* Organising committee.

Original Research Article

Received 23 September 2019
Accepted 02 October 2019
Published 15 October 2019

ABSTRACT

A field experiment was carried out at Krishi Vigyan Kendra, Katihar, Bihar in jurisdiction of Bihar Agricultural University Sabour, Bhagalpur during 2014 to 2018 with the objective to find out suitable crop residue management option under rice- wheat cropping system in Inceptisols of Seemanchal area of Bihar. The results after four years clearly indicates that the crop residue management practices involving incorporation of residues improved favorably and significantly the soil properties such as bulk density, infiltration rate, mean weight diameter, aggregate stability, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium, bacterial and fungal

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** Note: This paper was presented in International Conference on Crop Residue Management (ICCRM-2019), October 14-15, 2019, Patna, Organised by Bihar Agricultural University, Sabour, Bhagalpur - 813210 (Bihar), India. Conference organising committee completed peer-review of this manuscript.*

population, enzyme dehydrogenase and phosphatase activity in the soil and increased the grain yields of rice and wheat crop in the system over removal or burning of crop residue practices. Due to increased availability of readily decomposable organic matter in the form of crop residue and freshly incorporated green manure, the microbial population increased dramatically when crop residues are incorporated in the soil which might be responsible for increased enzyme phosphatase and dehydrogenase activity, decrease in bulk density, increase in granulation and aggregation and thus infiltration rate. The incorporation of crop residues with or without green manuring found promising for the environmental friendly and effective utilization of the crop residues under prevailing rice wheat system in this area.

Keywords: Crop residue management; burning; incorporation; retention; green manure; soil properties; crop productivity.

1. INTRODUCTION

Crop residues are important natural resources, and their effective recycling improves the soil physical, chemical and biological properties. On the basis of reported research results by different researchers, an analysis has been made that a rice-wheat sequence that yields 4 t ha^{-1} of rice and 3 t ha^{-1} of wheat removes more than 280 kg N, 26 kg P and 245 kg K ha^{-1} from the soil; the residues of rice and wheat amount to as much as 6-11 t ha^{-1} yr^{-1}. Indian farmers need to manage 4-6 t ha^{-1} of rice residues to overcome the problem for planting next crop particularly wheat and the management options available are: burning, incorporation, surface retention and mulching, and baling and removing the straw. Despite some advantages like killing of deleterious pests and clearing the piles before wheat planting, burning results huge losses of N (up to 76%), P (28%), K (18%) and S (27%), air pollution (@ CO_2 11 t ha^{-1}) depriving soils of organic matter (SOM). This loss of SOM is one of the recognized threats to sustainability. Incorporation leads to build up of SOM, soil N, P and K.

The major disadvantage of incorporation is the immobilization of inorganic N. However, N at 20 kg ha^{-1} as starter dose with straw incorporation increases yield of wheat and rice compared to burning. Surface retention of residue increases soil NO_3 - by 43%, N uptake by 33% and yield by 22% compared to burning. Residue management practices affect soil physical properties viz. soil moisture, temperature, aggregate formation, bulk density and hydraulic conductivity. Soil temperature is influenced through the change in radiant energy balance and insulation. Rice crop residues are highly siliceous and have the potential of transforming electrochemical properties of acidic soils that reduces P fixation; improving base retention and increasing the soil pH. Rice straw incorporation coupled with organic manure increases grain yield of wheat and improves soil physical condition. Residue incorporation results more microbial activity than residue removal or burning. Thus, if residues are managed properly, then it can warrant the improvements in soil properties and the sustainability in crop productivity. A large amount of crop residue is annually produced in the rice, wheat, maize growing countries. Moreover, the adoption of mechanized farming has resulted in leaving a sizeable amount of crop residues in the field after harvesting the grain.

There is enormous potential of recycling these residues in the crop production systems. Total amount of crop residue produced in India is estimated at 350 x 10^6 kg yr^{-1}, of which wheat residue constitutes about 27% and that of rice about 51%. Another estimate shows that 120 x 10^6 kg yr^{-1} rice residue, out of 180 x 10^6 kg yr^{-1} (assuming that $1/3^{rd}$ of the residue is used as feed for animals and other purposes) can be returned to the soil to enhance soil quality; it will contribute to soil 2.604 million tons of $N+P_2O_5+K_2O$, considering the nutrient contents in rice straw as 0.61% N, 0.18% P_2O_5 and 1.38% K_2O. In rice-wheat cropping system, the residues of rice and wheat amount to as much as 7-10 t ha^{-1} each year. Both rice and wheat are exhaustive feeders of nutrients and the double cropping system is heavily depleting the soil of its nutrient content. A rice-wheat sequence that yields 7 t ha^{-1} of rice and 4 t ha^{-1} of wheat remove more than N 300, P 30 and K 300 kg ha^{-1} from the soil. Another estimate shows that a 10 t ha^{-1} crop removes 730 kg NPK from the soil that is often not returned to the soils. If this residue is not returned this may cause mining of soil for major nutrients leading to net negative balance and multi-nutrient deficiencies in crops. This is one of the reasons for the yield decline in the rice-wheat system. Thus, there are urgent needs to manage the residues of these crops for sustainability and stability of the system (Krishna et al. 2004).

Today burning of crop residues become a challenging issue for scientist's community as well as policy makers worldwide because it directly affects our environment, soil health and the productivity of crops. There are many significant advantages of crop residue management one of them is increased organic carbon in soil which enhances water and nutrient retention capacity, greater microbial biomass and activity near the soil surface which acts as a reservoir for nutrients needed in crop production and increases structural stability and porosity. In addition to the altered nutrient distribution within the soil, changes also occur in the chemical and physical properties of the soil. Improved soil C sequestration through enhanced crop residue management practices a cost-effective option for minimizing agriculture's input with maximizing output. Besides supplying nutrients to the current crop, their residual effects on succeeding crops in the system are also important. Organic N is slowly mineralized and about 30% N, 60-70% P and 75% K is likely to become available to the first crop and rest to subsequent crops [12]. Therefore, it is urgent need to manage the crop residues. Keeping these facts in mind a field experiment was carried out at Krishi Vigyan Kendra Katihar with the objective to find out suitable crop residues management practice under rice- wheat system.

2. MATERIALS AND METHODS

The experiment has been carried out during 2014-2018 at farm field of Krishi Vigyan Kendra, Katihar, (Bihar Agricultural University Sabour, Bhagalpur) to study the impacts of crop residues management on soil physico-chemical, microbial properties and grain yields of crops. The study area lies between 25'N to 26'N Latitude and 87' to 88'E Longitude with an altitude of 32 m above MSL. The climate of the area is sub-tropical humid having mean annual maximum and minimum temperature 42ºC and 4^0C, respectively and the average annual rainfall of the district is about 1200 mm. The experimental soils comes under *Inceptisols* order and are non-calcareous, sandy clay in texture, light gray in colour and low to medium in organic C content. The land was prepared in each session as per treatments T_1- removal of crop residues, T_2 - burning crop residues, T_3 –incorporation of crop residues, and T_4 – incorporation of crop residues with green manuring, respectively with applied recommended dose of fertilizers inn all the treatments. The soil samples were collected from different plots in each year before sowing and after the harvesting of crops. The soil samples were analyzed using standard methods for different soil properties. Organic carbon content was determined by the Walkley and Black method [1], available nitrogen with alkaline $KMNO_4$ method [2], available phosphorous with Olsen's method [3] and available potash with Flamphotometrically method [4]. The pH and ECe were measured in soil suspension (1:2.5) using electrode [5] and microbial activities and biomass determined by chloroform fumigation extraction method [6]. The experiment was laid out in RBD with four treatments and four replications since 2014. After the harvested kharif crops the crop residues incorporated in soil by tractor driving plough and wheat seed sown by sowing machine, again after wheat harvest the dhaincha sown and incorporated after 45 DAS in soil and leave for 25 days in water logged condition in Kharif. The same processes are followed since 2014 to 2018. The data collected on different parameters under the experiment were statistically analyzed to obtain the level of significance using the computer MSTAT package program developed by Russell [7].

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of Soil

The data presented in Table 1 clearly indicates that the crop residue management practices involving incorporation of crop residues alone or in combination with green manuring improved favorably and significantly the physicochemical properties of soil in comparison to removal or burning practices of crop residues management. The soil bulk density decreased by 8.18 and 6.92 percent, infiltration rate increased by 28.13 and 18.75 percent, aggregate stability increased by 40 and 40 percent, electrical conductivity increased by 33.33 and 28.57 percent, organic C increased by 63.16 and 52.63 percent, available N increased by 29.21 and 15.17 percent, available P increased by 88.89 and 77.78 percent and available K increased by 40.96 and 40.43 percent, respectively under incorporation of crop residues with green manuring and incorporation of crop residues alone in comparison to the practice of burning of crop residues. However, no significant variation in pH was observed under different crop management practices. These findings are in conformity to the findings of Azmal et al. [8].

Table 1. Effect of Crop residue management in rice-wheat system on soil physicochemical properties (pooled data of 4 years)

Indicators	Crop residue management practices				CD (p=0.05)
	Removed	Burned	Incorporated	Incorporated + green manuring	
Bulk density (mg m^{-3})	1.57	1.59	1.48	1.46	0.02
Infiltration rate (cm h^{-1})	0.32	0.32	0.38	0.41	0.01
Aggregate stability (%)	9	10	14	14	0.04
pH (1:2.5)	6.7	6.7	6.8	6.8	NS
EC (d Sm^{-1})	0.20	0.21	0.27	0.28	0.01
OC (%)	0.40	0.38	0.58	0.62	0.14
Avail N ($Kgha^{-1}$)	175	178	205	230	2.82
Avail P ($Kgha^{-1}$)	20	18	32	34	0.46
Avail K ($Kgha^{-1}$)	190	188	264	265	0.84

Table 2. Effect of Crop residue management in rice-wheat system on soil microbial and enzymatic activities (pooled data of 4 years)

Indicators	Crop residue management practices				CD (p=0.05)
	Removed	Burned	Incorporated	Incorporated + Green manuring	
Bacteria (x 10^6)	14.5	2.6	28.36	32.25	2.04
Fungi (x 10^3)	58	11	105	125	15.83
Phosphatase activity (mg p-NP $g^{-1}h^{-1}$)	121	124	172	178	2.33
Dehydrogenase activity (mg $TPFg^{-1}$ 24 h^{-1})	32	29	55	65	1.07

Table 3. Effect of crop residue management on growth, yield attributes and yield of rice (Pooled data of 4 years)

Indicators	Crop residue management practices				CD (p=0.05)
	Removed	Burned	Incorporated	Incorporated + Green manuring	
Plant Height (cm)	92	95	105	110	2.3
Panicle (numbers m^{-2})	282	290	402	423	16
Panicle weight (g)	294	2.96	3.03	3.05	0.06
Filled grain (numbers $panicle^{-1}$)	124	126	135	138	1.04
1000 grain weight (g)	21.48	21.52	22.23	22.24	0.08
Grain yield (qt ha^{-1})	22	22	34	36	0.72
Straw yield (qt ha^{-1})	32	32	45	44	0.48
Harvest Index	0.41	0.41	0.43	0.45	-
Benefit : Cost ratio	2.31	2.35	3.02	3.10	-

3.2 Soil Microbial and Enzymatic Activities of Soil

The data related to soil microbial population and enzymatic activities have been presented in Table 2. It is clear from the data that the soil microbial population and enzymztic activities were increased positively and significantly under incorporation of crop residues with green manuring practice. An increase in bacterial population by1140.38 and 990.77 percent were recorded under incorporation of crop residues with green manuring and incorporation of crop residues practice, respectively. Similar trend was also found in case of population of fungi where increase in population was to the tune of 1036.36 and 854.55 percent respectively. Enzyme phosphatase activity increased by 43.55 and 38.71 percent and dehydrogenase activity increased by 124.14 and 89.66 percent

Table 4. Effect of crop residue management on growth, yield attributes and yield of wheat (Pooled data of 4 years)

Indicators	Crop residue management practices				CD (p=0.05)
	Removed	Burned	Incorporated	Incorporated + Green manuring	
Plant Height (cm)	85	88	95	98	3.1
Panicle (numbers m^{-2})	611	645	740	757	21
1000 grain weight (g)	41.02	41.11	42.17	42.34	0.05
Grain yield (qt ha^{-1})	24	24	37	38	0.04
Straw yield (qt ha^{-1})	52	52	79	81	0.37
Harvest Index	0.46	0.46	0.47	0.47	-
Benefit : Cost ratio	2.80	2.87	3.35	3.42	-

respectively under incorporation of crop residue with green manuring and without green manuring.

3.3 Performance of Crops

The data related to performance of rice and wheat crops have been presented in Tables 3 and 4. The growth and yield attributes of rice and wheat crops increased significantly under incorporation of crop residues with green manuring over incorporation of crop residue alone or removal or burning of crop residue practices. As far as growth, yield attributes and yield of crops are concerned, the incorporation of crop residue alone was found significantly superior over removal or burning of crop residue practices possibly due to improved physical, chemical and biological properties of soils due to increased organic C content in the soil.

The yield of rice and wheat were increased by 63.64 and 54.55 percent under incorporation of crop residues with green manuring and by 58.3 and 54.17 percent under practice of incorporation of crop residues alone in comparison to the practice of burning of crop residues. Consequently, the benefit: cost ratios of rice and wheat crops were also increased by 31.91 and 19.16 percent respectively, under incorporation of crop residues with green manuring and 28.51 and 16.72 percent with incorporation of crop residues alone in comprising to burning of crop residues. It was become possible due to increase in yields of crops might be due to improvement in different soil physicochemical properties, population of microorganisms and enzymatic activities. The results clearly showed that continuous recycling of crop residues for 4 years in rice-wheat-dhaincha system markedly influenced the soil properties and productivity of crops. Similar results were also obtained by Gupta et al.[9], Mandal et al. [10] and Sharma and Bali [11].

4. CONCLUSION

The significant improvement in different soil physicochemical properties, bacterial and fungal population and enzyme dehydrogenase and phosphatase activity in the soil and increase in the grain yields of rice and wheat crop in the system were found under incorporation of crop residue alone or in combination with green manuring over removal or burning of crop residue practices. Due to increased availability of readily decomposable organic matter in the form of crop residue and freshly incorporated green manure, the microbial population increased dramatically under incorporation practice of crop residue which might be responsible for increased enzyme phosphatase and dehydrogenase activity, decrease in bulk density, increase in granulation and aggregation and thus infiltration rate.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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