RESPONSE OF WHEAT TO WETLAND AND DRYLAND RICE TILLAGE, CROP RESIDUE INCORPORATION AND RATE OF FERTILIZER N APPLICATION IN RICE-WHEAT ROTATION ON COARSE ALFISOL OF EASTERN INDIA

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ABSTRACT

Tillage in combination with crop residue incorporation and application of fertilizer N at different rates are the main management options for the rice-wheat cropping system in Eastern India. A field experiment was conducted at IIT, Kharagpur to find out the impact of tillage, crop residue and rate of fertilizer N application on soil properties and yield of rice and wheat crops. The results of the experiment revealed application puddling increased the bulk density of soil measured after the harvest of rice or wheat crops. Puddling also decreased the saturated hydraulic conductivity, which in turn increased water retention of the soil and increased the yield of transplanted rainfed rice (TR). Yield of direct seeded rice (DR) grown in soil tilled with cultivator followed by disc harrow, was comparatively lesser than the grain yields of TR. The tillage treatment (cultivator followed by disc harrow) for wheat succeeding both TR and DR was same but yield of wheat crop succeeding DR was more than wheat succeeding TR. This phenomenon manifested that the practice of puddling though increased the yield of TR, the compaction caused by it reduced the yield of wheat crop. Incorporation of rice and wheat crop residues either singly or in combination increased the soil organic carbon content in both of the tillage treatments but the increase was more with dryland tillage under direct seeded rice-wheat-fallow system. The return of carbon to soil and yield of crops was maximum when both rice and wheat residues were added along with fertilizer N @ 120 kg N /ha.

INTRODUCTION

Rice and wheat are the important crops, which are grown in rice-wheat-fallow sequence in most parts of India. Both lowland irrigated/rainfed transplanted rice and upland irrigated/rainfed direct seeded rice is followed in northern and eastern parts of India with different tillage practice for transplanted and direct seeded rice. The tillage used for lowland transplanted rice is puddling or heavy wetland tillage, whereas, heavy or light dryland tillage is practiced for direct seeded rice.

Puddling or wet tillage in rice is used mainly to decrease the water loss through seepage as puddling or wet tillage reduces total water porosity and changes porosity distribution, which increases water storage. Puddling also leads to destruction of soil structure (Sawhney and Sehgal, 1989) as a result, it influences various soil hydraulic properties, reduces percolation of water and retains standing water in the field, which in turn reduces the irrigation requirement (Hobbs et al., 2000). It also changes the distribution of soil separates, leaving the clay particles in the surface soil layer. In this way, tillage may further improve the soil textural condition and increase water retention, if incorporation of crop residues also accompanies it (Bhagat, 1990). Crop residue has an innate property to condition the soil and prevent the loss of nutrients and soil-water, increases the water and nutrient holding capacity of soil, as well as preserves the soil structure (Lal, 1993). So, the incorporation of crop residue not only increases the soil and crop productivity, it is the best alternative to recycle the organic carbon to agricultural land and to conserve C and N in organic form. Nitrogen application is another management practice, which gets affected by tillage operation and its requirement varies with the different tillage practices. So it is very essential to detect the optimum level of N to be applied under specific tillage practice and crop residue application, for sustainable productivity with no detrimental effect on environmental consequences and also reduce the cost of production.

Thus tillage, crop residue incorporation and fertilizer N application are the three major management practices, which determine the successful and sustainable production of rice-wheat system in India. Therefore, a study was conducted to understand the combined effect of tillage practice, crop residue and N application rates on the productivity of Rice-wheat system and also to identify the best combination tillage and optimum rate of crop residue and N for this soil. Conservation of natural soil environment and enrichment of soil organic matter were the other objectives included in the scope of this study.

OBJECTIVES

The objectives of the present study were to

i) assess the effect of tillage practices on rice followed by wheat crops
ii) determine the influence of crop residue application on soil properties and crop productivity
iii) select the best combination of crop residue and N application rate under puddling and dryland tillage practices.

MATERIALS AND METHODS

Experimental Site

A field experiment was conducted at the experimental farm of Indian Institute of Technology, Kharagpur, which is situated in Red and laterite agroclimatic zone of the state West Bengal, India. Kharagpur is intersected by 22.19′ N latitude and 87.19′E longitude. The farm is situated at an altitude of 48m above the mean sea level.

Climate

The climate of Kharagpur is subhumid, subtropical characterized by hot and humid during summer months (April and May), rainy during June to September, autumn during October and November, cool and dry winter in December and January and moderate spring in February and March. The average maximum and minimum temperature and rainfall during rice growing season were 32.367± 0.21^{0}C, 25.000± 0.720^{0}C and 7.633± 1.250mm/day. Whereas, 28.145± 1.054^{0}C, 15.915± 0.445^{0}C and 0.54± 0.622mm/day were the average maximum, minimum temperature and rainfall noted during wheat growing season.

Soil

The soil of the experimental site is lateritic sandy loam, classified under great group of 'Haplustalf'. The soil is acidic in nature (pH 5.3) with electrical conductivity of 0.65 dsm^{-1}. The soil is low in organic carbon content (0.32%), CEC and nutrient and water holding capacity. The soil has high bulk density (1.62 Mg/m^3) and saturated hydraulic conductivity (12.80 cm/day).

Field Experiments

Rice-wheat cropping system was adopted for the study. Both transplanted rice (TR) and direct seeded rice (DR) followed by irrigated wheat were experimented following different management practices. Puddling with tractor drawn rotavator and dryland tillage with tractor drawn cultivator followed by disc harrow was practised as tillage treatments for wetland transplanted rice and direct seeded rice as well as wheat, respectively. At the time of land preparation for rice and wheat crops, wheat and rice crop residues were incorporated to soil @ 0 and 4 tonnes per ha. The rates of application of N fertilizer were at 0, 40, 60, 80, 100 and 120 kg/ha. N fertilizer (urea) in two splits 29 and 75 days after sowing for direct seeded rice, 14 and 46 days after transplanting in case of transplanted rice and 24 and 76 days after sowing in case of wheat crop. Whereas, recommended dose of P and K (50kg/ha of each P_2O_5 and K_2O) were applied in the form of single super phosphate (SSP) and mureate of potash (KCl) to both rice and wheat crops.

First crop, rice (cultivar IR36) was direct seeded at advent of monsoon in June 2001 and at the same day rice seeds were sown in the nursery plot separately which was later (nearly 21 days after sowing) transplanted in July in the puddled plot. The transplanted and direct seeded rice were harvested in October 2001. After the harvest of rice, wheat (Cultivar 'Sonalika') was sown in the month of November. Wheat was harvested in April, and after a short period of fallow, next rice was taken. Rice was grown as rainfed crop but wheat was irrigated with 6 cm water timed at IW/CPE ratios of 0.6. The grain yield of rice and wheat crops was recorded after harvest and biomass of wheat was recorded at boot leaf stage of the crop.

Soil Analysis

Soil samples were collected after harvest of each crops, processed and kept in dry place for further analysis. Organic carbon content of soil was estimated by the modified Walkley-Black method (Walkley and Black 1934). The experimental soil was analysed for basic chemical and physical properties following standard methods discussed as follows: pH in water was measured by glass electrode (Jackson, 1967), cation exchange capacity following the method described by Hesse (1994), bulk density by Blake (1965), saturated hydraulic conductivity by Laboratorium permeameter following the principle of Klute (1965).

RESULTS AND DISCUSSION

Impact of Tillage and Crop Residue Incorporation on Soil Properties

I) Impact of Tillage and Crop Residue Incorporation on Soil physical properties

The application of both wetland and dryland rice tillage increased the bulk density (BD) of soil but the increase in BD varied differently under wetland and dryland tillage (Table 1). Increase in BD was more under the treatment of puddling than dryland rice tillage. The increase in BD was less when crop residues were added and it was minimum when residues of both rice and wheat crops were applied. Intensive puddling by rotavator decreased the saturated hydraulic conductivity (Ks) from 12.80 to 7.81 cm/day (Table 1). The decrease in Ks was more under puddling treatment than dryland tillage with cultivator followed by disc harrow. The decrease in

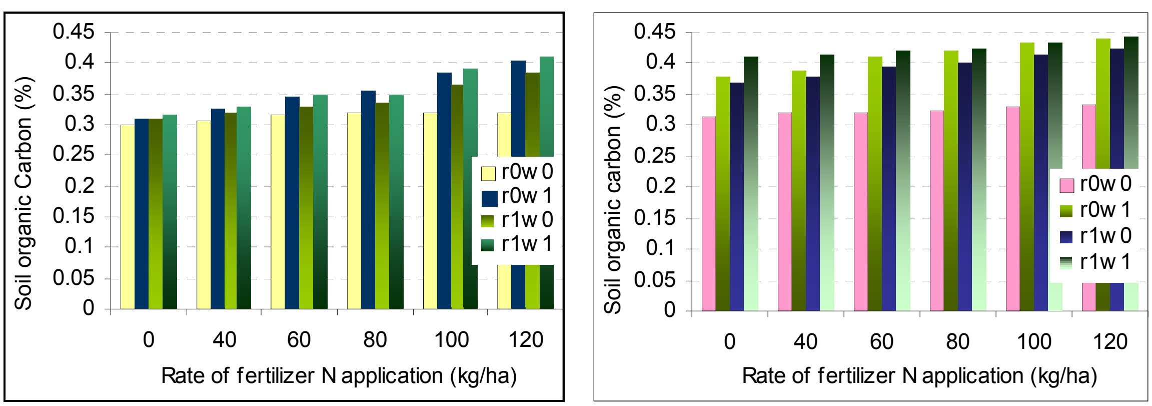
Ks was reduced when rice or/and wheat crop residues were incorporated and decrease was minimum when both rice and wheat crop residues were added.

BD decreased after the harvest of wheat following both transplanted (TR) and direct seeded (DR) rice but the decrease in BD was lesser in the soil where wheat was grown following transplanted rice. The difference in Ks, recorded after wheat following TR and DR, was very less. The impact of crop residue application on Ks after wheat harvest was same as it was found after rice harvest. The maximum Ks was recorded when residues of both rice and wheat crops were incorporated. Decrease in bulk density of surface soil with the application of crop residues might be due to increase in soil porosity (Joshi et al., 1994), which ultimately increased the Ks of soil (Boparai et al., 1992).

The difference in soil penetration values noted after harvest of wheat (2002-03) following TR and DR revealed that the soil under wheat following TR was more compact that the soil under wheat following DR (Table 2). This also manifested that the impact of puddling to the soil was such prominent that wheat tillage could not reduce it also.

II) Impact of Tillage, Crop Residue Incorporation and rate of fertilizer N application on Soil Organic Carbon (SOC)

Puddling with rotavator decreased SOC in transplanted rice-wheat-fallow (TR-W-F) system than dryland tillage followed for direct seeded rice-wheat-fallow (DR-W-F) system (Fig. 1). Similar was the findings of Doran (1980). Application of rice and wheat residues either individually or in combination increased SOC over that with no residue application (r_0w_0). The maximum SOC occurred with r_1w_1 under both TR-W-F and DR-W-F system. So, the return of organic carbon to soil is more in DR-W-F than in TR-W-F system. In other words, it can be said that the effect of puddling was negative for enrichment of SOC pool. Increase in rate of fertilizer N application increased the SOC content and SOC content was maximum at N_{120}.



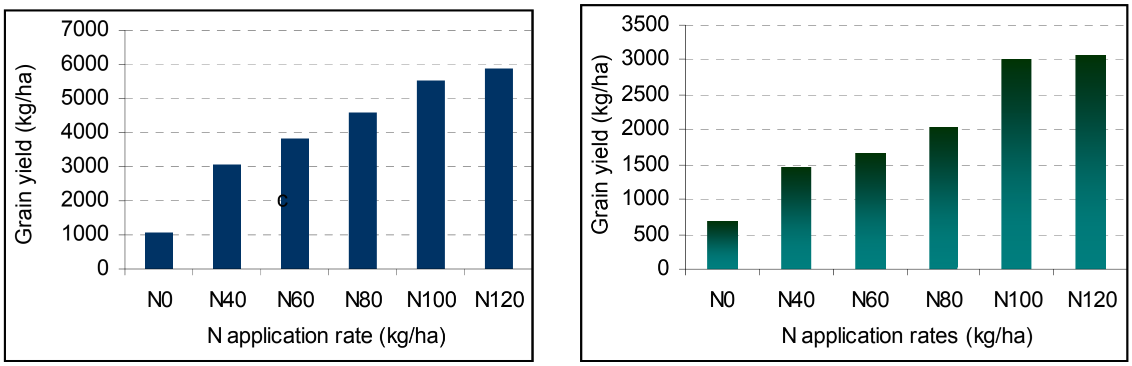
(a) (b)

Fig. 1 Effect of different combination of tillage and crop residue treatments on soil organic carbon under transplanted rice-wheat-fallow and direct seeded rice-wheat-fallow system.

Impact of Tillage in Combination with Crop Residue and N Incorporation on Yield of Rice and Wheat Crops

I) Yield of Rice

The yield of transplanted rice (2001) was higher than the yield of direct seeded rice (Fig. 2). This revealed that the intensive puddling with rotavator decreased Ks (Table 1) and increased water retention of the light sandy loam soil of Kharagpur. Increase in rate of fertilizer N application increased the yield positively but difference in yield at N_{100} and N_{120} was less (Fig. 2b).

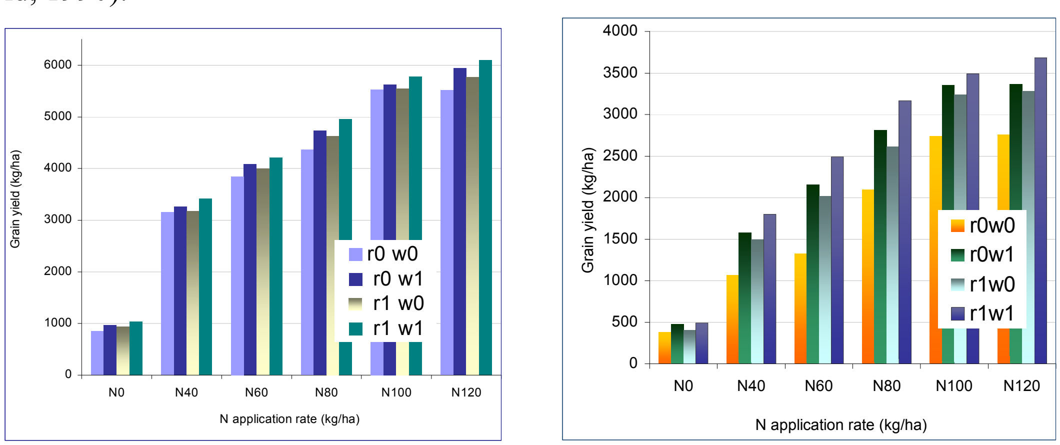


(a) (b)

Fig. 2 Grain yields of transplanted (a) and direct seeded (b) rice (2001) under different N application rates.

In 2002, the effect of tillage was same as in 2001. The yield of both transplanted and direct seeded rice was increased with application of rice and wheat crop residue singly or in combination. The yield was maximum with incorporation of both rice and wheat crop residues. Increase in direct seeded rice yield was noted as much as 34% at N_{120} level of N application. This manifests that a long term application of crop residues may increase the SOC level and help retain water in soil tilled with cultivator followed by disc harrow also.

The grain yields of transplanted and direct seeded rice also increased with increase in rate of fertilizer N application. Increases in N application rate increased SOC in surface layer, which helped retain the mineral N and its release in the later stages to be used by rice plants (Smith and Whitfield, 1990).

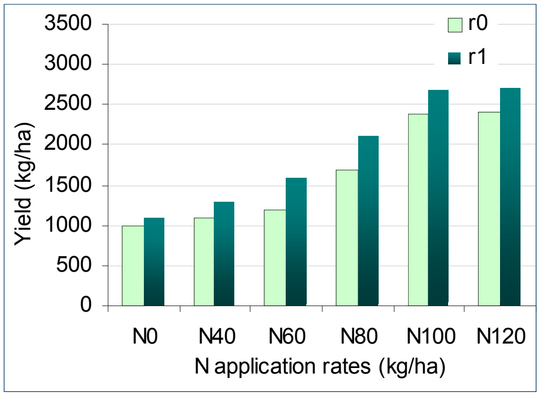


(a) (b)

Fig. 3 Grain yields of transplanted (a) and direct seeded (b) rice (2002) under different treatment combinations of crop residues and N application rates.

2) Yield of Wheat

Grain yield of wheat (2001-02) following direct seeded rice was a little higher without any residue and distinctly higher with application of rice residue than wheat following transplanted rice (Fig. 4). Less yield of wheat following TR manifests that the compaction of soil by puddling had malefic effect on wheat growth and yield. Increase in rate of fertilizer N application increased the yield of wheat succeeding both transplanted and direct seeded rice and was noted maximum with application of fertilizer N @120 kg N /ha.



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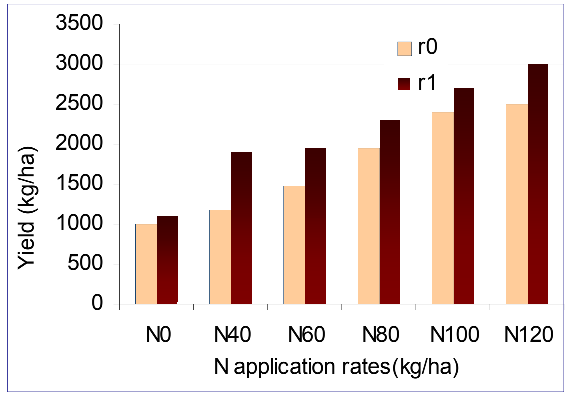

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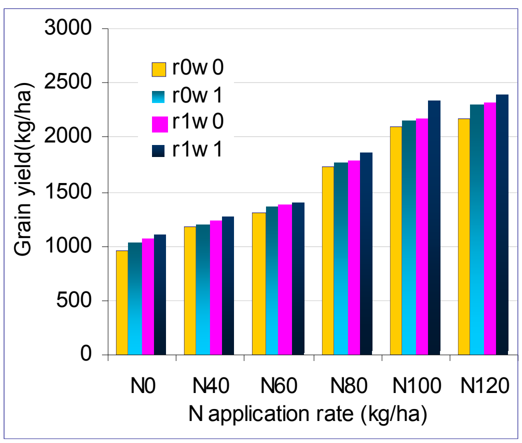
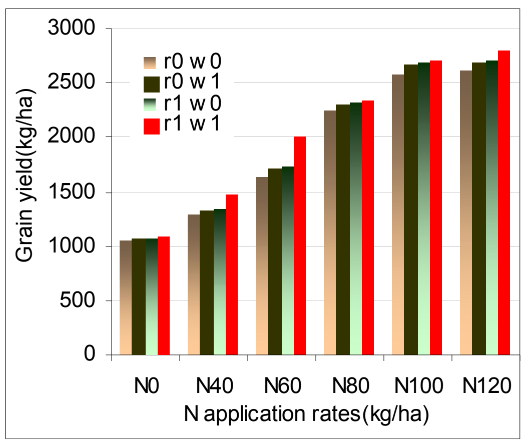
Fig. 4 Grain yields of wheat (2001-02) following transplanted (a) and direct seeded (b) rice under different treatment combinations of crop residues and N application rates.

The difference in yield of wheat (2002-03) succeeding transplanted and direct seeded rice was similar as it found in 2001-02 (Fig. 5). The incorporation of rice and wheat residues singly or in combination increased the wheat yields and it was maximum when both rice and wheat residues were applied.



(a)



(b)

Fig. 5 Grain yields of wheat (2002-03) following transplanted (a) and direct seeded (b) rice under different treatment combinations of crop residues and N application rates.

SUMMARY AND CONCLUSION

Wetland tillage or puddling reduced the yield of wheat following transplanted rice crop. This study revealed that incorporation of crop residues has great potential to improve the status of soil organic matter and increase the yield of rice-wheat cropping system. Crop residue application is also effective in reducing the malefic effect of puddling to wheat succeeding transplanted rice crop. Though the yield of wheat following direct seeded rice crop is higher than the yields of wheat succeeding transplanted rice crop, yield of direct seeded rice is lesser than yield of transplanted rice crop. Application of both rice and wheat crop residues can mitigate the malefic effect of puddling on wheat succeeding transplanted rice crop. The treatment combination comprised of incorporation of rice and wheat crop residues along with application of fertilizer N @120 kg N/ha produced maximum grain yield of rice and wheat crops.

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Table 1 Influence of tillage and crop residue application on soil bulk density and saturated hydraulic conductivity of surface soil (0-15cm).

Tillage treatments	Crop residue treatments	Rice (2002)		Wheat (2002-03)	
		Bulk Density (Mg/m^3)	Saturated Hydraulic Conductivity (cm/day)	Bulk Density (Mg/m^3)	Saturated Hydraulic Conductivity (cm/day)
Puddling + wheat tillage with Cultivator & Disc Harrow	r_0w_0	1.75	7.81	1.67	12.51
	r_0w_1	1.74	7.95	1.66	12.70
	r_1w_0	1.73	8.24	1.65	12.82
	r_1w_1	1.68	8.48	1.65	12.96
Dryland rice tillage + wheat tillage (Cultivator & Disc Harrow)	r_0w_0	1.68	10.35	1.65	12.40
	r_0w_1	1.67	10.64	1.64	12.50
	r_1w_0	1.65	10.85	1.64	12.62
	r_1w_1	1.63	10.92	1.63	12.80

Table 2 Influence of rice and wheat tillage on soil penetration .

	Soil depth (cm)	Soil penetration (kg/sq. cm)
Puddling + wheat tillage with Cultivator & Disc Harrow	2.54	13.55
	7.62	14.46
	12.70	15.14
Dryland rice tillage + wheat tillage (Cultivator & Disc Harrow)	2.54	12.44
	7.62	13.02
	12.70	14.71