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Improving Soil and Crop Productivity through Resource Conservation Technologies in Drought Prone Area

M. I. Hossain[1], M.E. Haque[2], M.R.I. Mondal[1] and M K Sultan[1]

[1]Bangladesh Agricultural Research Institute, iliasrwrc@gmail.com, dg.bari@bari.gov.bd, dir.res@bari.gov.bd [2]Murdoch University, Australia, enamul.haque71@gmail.com

Introduction

Resource conserving technologies (RCTs) provides immediate economic and environmental benefits of crop establishment and thus improve systems yield. Rice is transplanted in flat fields that are typically ponded for long periods that negatively affect soil properties for the non-puddled crop (Kumar et al. 2000). Yields of rice and wheat in heat and water-stressed environments can be raised significantly by adopting RCTs, which minimize unfavorable environmental impacts, small and medium-scale farms (Kataki, 2001). Inclusion of grain legumes in rice-wheat cropping system may be another option for increasing cropping intensity, soil fertility and productivity. Crop residue, raised beds along with efficient N fertilization strategies are likely to be key components of increase crop productivity and soil fertility. Thus, crop residue management under bed systems along with efficient N fertilization strategies were assessed the potential productivity and soil fertility in rice-wheat system.

Materials and methods

A wheat-mungbean-rice cropping pattern was implemented over 9 years at RWRC, BARI, Rajshahi, Bangladesh ($24^0$3'N, $88^0$41'E, 18 m above sea level). The site has a drought prone environment and is located in AEZ 11 with course-textured soil (BARC 2007). The area receives only 757 mm mean annual rainfall, about 97% of which occurs from May to September. Soil at the site is a calcareous silty loam with slightly alkalinity (pH 7.5), low OM (0.8%) and low N (35 µ/g soil). The experiments consisted of 20 subplots with four tillage/straw treatments (30% straw retention(SR)+permanent raised bed(PRB), 30% SR +conventional tillage (CTP), 0% SR + PRB and 0% SR + CTP) and five N levels (0, 40, 80, 100 and 120% of recommended nitrogen) with three replication. Total system productivity (TSP) for each treatment was calculated based on equivalent yields as follows: (rice grain yield*1.35) + (wheat grain yield*1.39) + (mungbean grain yield*1.54). N-uptake by grain and straw were calculated by the following formulae:

N-uptake by grain (kg ha^{-1}) = Total N (%) in grain x grain yield (kg ha^{-1})/ 100

N-uptake by straw (kg ha^{-1}) = Total N (%) in straw x straw yield (kg ha^{-1})/ 100

Results and discussions

a) Total system productivity

TSP increased 10-12% for all crops in 30% straw retention with PRB over conventional (Figure 1). TSP of rice, wheat and mungbean was 12 t/ha per year. Lower TSP also occurred from 0% SR with CTP due to reduced crop growth. Similar observations were made by Singh (2003) in Mexico. TSP significantly increased by 11% in rice, 14% in mungbean with increasing N levels up to 100%; and by 16% in wheat up to 120% N level (Figure 2). Highest TSP occurred in PRB with 120 kg N/ha in wheat and 80 kg N/ha in rice, 20 kg N/ha in mungbean. Lower TSP also occurred from 0% N with CTP due to less N uptake. Similar observations were made by Yadvinder Singh et al. (2006). Averaged over 9 years, PRB + 30% SR increase 17% wheat yield, but there was no significant mungbean yield increase with additional N with 30% SR. Average rice yield on PRB + 30% SR with 80% N was significantly higher than with 0% SR at the same N rate, and there was no further yield increase at higher N rates.

b) Nitrogen uptake

N uptake was significantly (P<0.5) influenced by straw retention and N levels. Increased N uptake was 31% in rice, 25% in wheat and 19% in mungbean over conventional (Figure 3). In PRB+30% SR plots, total N uptake was maximum at 50-100% by rice, 80-120% by wheat and 50-100% by mungbean. Limon-Ortega et al. (2000) observed that permanent beds with straw retention gave the highest average wheat grain yields (5057 t/ha), N use efficiency (28.2 kg grain/kg) and total N uptake (133 kg/ha).

c) Environmental impact

Fuel used both conventional and reduced tillage system was showed in (Table 1). 54 litre/ha/year diesel used for PRB system where 96 litre/ha/year also used in conventional method. PRB tillage system saved 42 litre/ha/year of costly diesel fuel which 44% less emission of CO_2 into the atmosphere. Witt et al. 2002 reported same results from their experiment.

d) Soil organic matter (SOM)

After 9 years (2004 to 2013), increased organic matter by 0.72% (Table 2) from 30% SR both rice and wheat straw and full residue retention from mungbean crops with PRB system into the soil. Also P, K, S, Zn, B availability increased from 30% SR in same cases of residue retention. Kumar and Goh (2000) reported that, in the longer term, residues and untilled roots from crops can contribute to the formation of SOM.

e) Changes of soil physical propertise

After 9 years, lower bulk density was found from PRB over conventional from different depth, increased infiltration rate and total pore space in same due to create loose soil into bed with increase soil microorganisms.

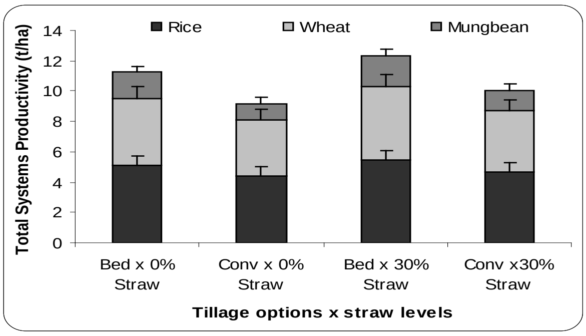

Figure 1. TSP under tillage options & straw levels in rice-wheat-mungbean system

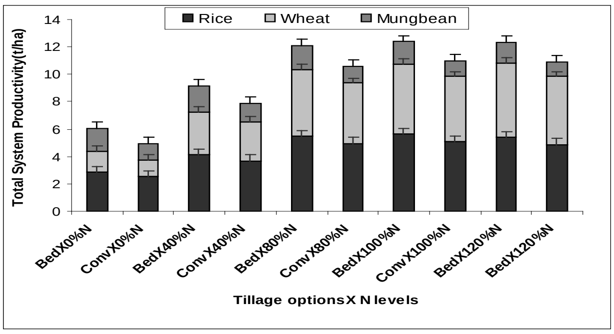

Figure 2. TSP under tillage options & N levels in rice-wheat-mungbean system

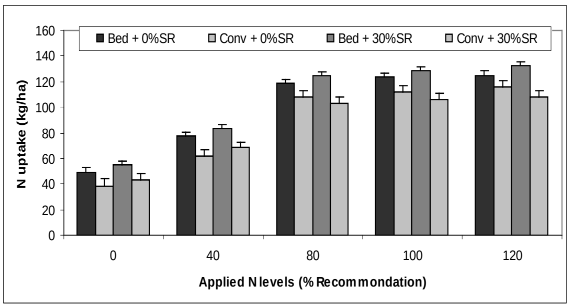

Figure 3. Total N uptake under different tillage options & N levels

Table 1: Comparative use of diesel fuel and CO_2 emission on raised bed & traditional

Tillage options	Diesel used (litre/ha /year)	CO_2 emission (kg/ha /year)	Less CO_2 emission (%)	Fuel saved (litre/ ha/year)
PRB	54	140.4	44	42
Conv.	96	249.6	-	-

Table 2. Chemical properties changes after 9 years crop cycles

Characteristics	Initial	Final	Differ
Organic Matter (%)	0.90	1.62	+ 0.72
Total N (%)	0.12	0.19	+ 0.07
Exch.K (ml eq/100g soil)	0.26	0.48	+ 0.22
Avail. P (mg / g soil)	24.5	52.5	+ 38.0
Avail. S (mg / g soil)	25.6	38.9	+ 13.3
Avail.Zn (mg/g soil)	0.84	6.13	+ 5.29
Avail. B (mg /g soil)	0.19	0.37	+ 0.18

Table 3. Physical properties changes after 9 years crop cycles

Tillage options	Bulk density (mgm^{-3})			Infiltration rate (cmh^{-1})	Total pore space (vol.%)
	0-10 cm	10-20 cm	20-30 cm		
Bed	1.37	1.59	1.74	0.85	53-59
Conv	1.57	1.79	1.95	0.59	43-48
LSD(0.05)	0.037	0.025	0.034	0.032	NS

Findings

Permanent beds with 80, 100 and 120% recommended N application were found similar performances over all treatments with 30% straw retention. It was also found that 120% N application with conventional tillage practice were obtained similar yield compare with 80% N under permanent bed system for 30% straw retention. 0.72% OM increased after nine years crop cycles for 30% residue retention from wheat & rice and full residue retained from mungbean crops. Save 20% N after nine years crop cycles after residues retention from all three crops.

Conclusions

80% N with 30% straw retention from wheat & rice and full residue retained from mungbean crops under permanent beds were the best combination for getting higher productivity as well as improve soil fertility in Bangladesh.

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