

Effect of Tillage Options and Straw Management on Crops Productivity and Soil Fertility in Rice-Wheat-Cropping Pattern

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Abstract. A field experiment was conducted during winter season to study the productivity under three N fertilizer levels (80, 100 and 120% N of recommended dose), two levels of straw retention (0 and 30%) and three tillage options (permanent raised bed, fresh bed and conventional tillage practice) in a Rice-Wheat cropping system. Tillage options have been found to affect thousand grain weight (TGW) and grain yield where 49.6, 52.9 and 54.7 g for TGW and 3.77, 3.98 and 4.41 t/ha for grain yield for conventional, permanent bed and fresh bed, respectively were found for wheat. The spikes/m² was 343, 322 and 337 while, the spikelets/spike were recorded as 17.2, 17.6 and 17.8 for conventional, permanent and fresh bed, respectively. Different tillage options were found to cause the formation of grains/spike, 43.2, 49.7 and 50.8, respectively. Therefore, other yield components were assumed to be enhanced in response to fresh bed tillage option. Fresh bed with 30% straw retention produced highest productivity and similar results were also obtained from permanent beds with 30% straw retention. Fresh bed with 120% recommended N produced the highest productivity for wheat which was similar to permanent bed with 120% N. The increase in yield was associated with progressive increase in all growth components and will give a new insight to identify the strategy for the development of wheat and other crops cultivation.

Keywords: tillage options, N fertilization, straw management, sequential cropping system, wheat yield

Introduction

Land degradation and soil fertility decline are among the main causes of the stagnation and fall of agricultural production in many tropical countries, including those with intensive irrigated cropping systems. Approximately 85% of the area planted with intensive rice-wheat (RW) sequential cropping is found in the Indo-Gangetic Plain (IGP) of South Asia in India, Pakistan, Nepal and Bangladesh (Timsina and Connor, 2001). Rice is transplanted in flat fields typically ponded for long periods or continuously from transplanting until shortly before harvest. This negatively affects soil properties for the following non-puddle crop (Sah *et al.*, 2014). Wheat is then planted in these structurally disturbed soils, often after many tillage operations to prepare the seedbed or increasingly with little soil disturbance using zero-till seed drills. A change from growing crops on the flat to raised beds offers more effective control of irrigation water and drainage. This may be particularly beneficial for non-rice crops grown in rotation with rice, allowing better rainwater management during the monsoon season for rice. Connor *et al.* (2003) suggested that permanent raised beds might offer farmers further significant

advantages such as increased opportunities for crop diversification, mechanical weeding and placement of fertilizers; relay cropping and inter-cropping; and reduced tillage and water saving. There are also indications that crop yields from beds can be further increased by using higher rates of N fertilizer and later irrigation because of the reduced risk of lodging (Wei *et al.*, 2008). Raised beds are increasingly used in many developed and developing countries in mechanized agriculture but have been introduced only recently in Bangladesh, with the aim of improving system productivity (Talukder *et al.*, 2002). The common practice of rice in puddle soils destroys the soil physical structure that has implications for the following wheat crop (Naresh *et al.*, 2014). The successful growth of rice on raised beds in northern Australia (Roth *et al.*, 2005) and high yielding irrigated wheat in Mexico under bed were observed. Alteration and development of tillage shows influences on soil fertility and soil environment thereby causing wheat productivity. Although different tillage options have been performed to enhance wheat yield and cultivation in developed countries however, much evidences are not observed in Bangladesh regarding the usage of conventional, permanent and fresh bed system on wheat production. Therefore, wheat yield and yield components

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were assumed to be enhanced in response to these different tillage options.

Crop residues are an important source of soil organic matter vital for the sustainability of agricultural ecosystems. About 25% of N and P, 50% of S and 75% of K uptake by cereal crops is retained in crop residues, making them valuable nutrient sources (Singh, 2003). However, straw retention is not a common practice in the rice-wheat (RW) systems of Bangladesh, as is also the case elsewhere in South Asia. Wheat and rice straw are usually removed from fields for use as cattle feed and for purposes such as livestock bed ding, thatching material for houses or for fuel, leaving little for incorporation into the soil. The exception is in the north-western IGP, where most of the rice residues are burnt. Due to the limited number of livestock, farmers throughout the IGP have access to very limited amounts of organic manure. As a result, soil organic matter levels have declined in these cropping systems, and optimization of nutrient uptake and absorption efficiency has become one of the most important goals in crop production strategies. Talukder *et al.* (2002) reported that N use efficiency was highest in permanent raised beds, giving higher yields than a conventional system. Limon-Ortega *et al.* (2000) observed that permanent beds with straw retention had the highest mean wheat grain yields (5.57 t/ha), N use efficiency (28.2 kg grain/kg of N supply) and total N uptake (133 kg/ha), with positive implications for soil health. Thus, crop residue management and beds, along with efficient N fertilization strategies, are likely to be key components of new farming practices that can increase and maintain yields from the intensive RW system in Bangladesh. Straw management with conventional, permanent and fresh bed cropping system might be involved in influencing wheat productivity. Thus the current research was undertaken with the following objectives:

- Performances of bed planting system over conventional and the effect of tillage options on wheat yield and yield components;
- Interaction effect of tillage options and straw management on yield and N-use efficiency;
- Interaction effect of tillage options and N fertilization on wheat productivity.

Materials and Methods

A cool season wheat (*Triticum aestivum*)-spring mungbean (*Vigna radiata*)-monsoon rice cropping pattern was implemented starting with wheat sown in

November 25, 2010 at the Regional Wheat Research Centre, Shyampur (RWRC), Rajshahi, Bangladesh (24°3'N, 88°41'E, 18 m above sea level). The site has a subtropical climate and is located in Agro Ecological Zone 11 (High Ganges River Flood Plan) on flood-free high land, with coarse-textured, highly permeable soil. The area receives 1,257 mm mean annual rainfall, about 97% of which occurs from May to September. Total rainfall was highest during the mungbean season and lowest in the wheat season in all years.

The experiment was conducted at Regional Wheat Research Centre, Rajshahi Research Farm to find the effect of fertilizer placement with different tillage options established in the research farm on wheat yield. The three tillage options (permanent raised bed, fresh bed and conventional tillage practice) in a RW cropping system were considered. The experiment was conducted in split plot design with three replications. Wheat variety Prodig was planted at the nationally recommended seeding rate of 100 and 120 kg/ha for beds and conventional layout, respectively in early December (2nd December, 2010 and 2011) and harvested in late March (28th March, 2011 and 2012). The trial was originally established as a permanent raised bed (PRB) experiment with two straw management practices (main plots- 30% and 0% straw retention SR) and three N levels (subplots 80%, 100%, and 120% of recommended). The area of each subplot was 15 m² (5m× 3m). The recommended applied NPK rate on wheat crop was N(100), P(30), K(50), S(20), kg/ha. Soil analysis has been done by Kjeldahl titration method (Kjeldahl, 1883). Mineral nutrient was available from grain and straw for NPK with Olsen titration method (Olsen *et al.*, 1954). With wheat, two-thirds of the N was applied before seeding and the remaining one-third at crown root initiation (CRI) (Zadoks growth stage 1.3). Sufficient irrigation water was applied to fill the furrows between the raised beds while the flat plots were flood irrigated. The wheat received three irrigations at CRI (Z1.3), booting (Z4.0-4.9) and grain-filling stages (Z8.0-8.9). Generally, both conventional tillage practice (CTP) and permanent raised bed (PRB) were irrigated on the same days, but less water was needed to fill the furrows with PRB compared to CTP. Manual weed control was done after the first irrigation for wheat.

Statistical analysis of data. MSTAT-C and Microsoft Excel and DMRT were used to measure the variation of mean data of treatments. Treatment means were compared at $P \leq 0.05$. The data were analysed statistically

following computer package MSTATC. All the data were statistically analysed following the ANOVA technique and the significance of mean differences was adjusted by Duncan's Multiple Range Test.

Results and Discussion

Analysis of soil composition. Before experimentation initial soil sample was collected and analysed to know the nutrient status and the results were presented in Table 1 and 2. The soil was slightly alkaline (7.8 pH) having low organic matter content (0.94%) and the total N content was very low (0.05%). Different elements were also analysed from the soil where medium K level (0.21 M_{eq}/100 g) was observed. In soil P, S and Zn contents were 10, 23.3 and 0.14 µg/g, respectively. In addition, the boron content was found to be very low (0.27 µg/g). The results regarding the soil composition and other parameters reveal that the overall soil fertility status was low.

Effect of tillage options on yield and yield components.

As demonstrated in Table 3, grain yield and yield attributes were used to find different tillage options on the development of wheat yield along with other parameters regarding the yield. Although tillage options did not significantly influence on the grain yield and yield components of wheat however, the highest grain yield was found from fresh bed (4.41 t/ha) which was similar to conventional (3.77 t/ha) and permanent bed (3.98 t/ha). Similar trends were found in yield attributes. Therefore, only tillage options are not associated in

Table 1: Fertility status of initial soil sample of the experimental site at RWRC, BARI, Rajshahi

Sample	pH	OM (%)	Total N (%)
Value	7.8	0.94	0.05
Critical level	-	-	0.12
Interpretation	Slightly alkaline	Very low	Very low

Table 2: Elemental analysis of initial soil sample of the experimental site at RWRC, BARI, Rajshahi

Sample	K M _{eq} /100g	P	S µg/g	Zn	B
Value	0.21	10	23.3	0.14	0.27
Critical level	0.12	10	10.0	0.60	0.20
Interpretation	Medium	Low	Opt.	Very low	Very low

alterations of inducing the wheat yield and yield attributes and other factors might be involved in this respect. Wheat crop development throughout the season clearly depends on tillage, crop residue management and amount and timing of N fertilization. Rather than the retention of crop residue as such, the combination of crop residue retention and tillage will induce a change in the nitrogen cycle and as such the timing of N release (Govaerts *et al.*, 2006). Verhulst *et al.* (2009) found the effect of different tillage on wheat crop performance. They observed that the conventionally tilled bed-straw incorporated took off fast as compared to the permanent raised bed systems, but plant performance decreased abruptly two weeks after the first auxiliary irrigation. The tillage operations in conventional tilled-straw incorporated might induce a fast N mineralization at the beginning of the season. Tillage increases aggregate disruption, making organic matter more accessible to soil microorganisms (Six *et al.*, 2002) and increasing mineral N release from active and physically protected N pools (Kristensen *et al.*, 2000). Moreover, total dry matter (TDM) was significantly affected by tillage systems for the first year as demonstrated by Wiese (2013). Therefore, it is reasonable that alterations of tillage systems may induce the yield and yield components of wheat.

Interaction effect of tillage options and straw management.

Crop growth is the integrated evaluator of the efficiency of the chosen agricultural management system within the boundaries of the agro-ecological environment. Given a cultivar that has been selected for the agro-ecological zone, the crop forms the integrated evaluator of all environmental factors, including the influence of agricultural management and how it determines resource use efficiency. Yield can be measured as an end of season static result of seasonal crop performance, but this does not reflect within season

Table 3. Effect of tillage options on mean yield and yield components of wheat in 2010-11 and 2011-2012

Tillage options	Spikes/ m ²	Spikelets/ spike	Grains/ spike	TGW (g)	Grain yield (t/ha)(mean)
Conventional	343	17.2	43.2	49.6	3.77
Permanent bed	322	17.6	49.7	52.9	3.98
Fresh bed	337	17.8	50.8	54.7	4.41
CV (%)	13.14	5.34	7.59	3.65	12.44
LSD (0.05)	NS	NS	2.054	1.132	0.235

TGW=thousand grain weight

dynamics of crop performance and its relation with the production environment. In order to understand and evaluate cropping systems and to fine-tune resource management (N fertilizer), insight in crop performance over time is crucial. The effect of management factors, such as tillage systems and crop residue management on crop development during the crop cycle has not been studied intensively. As shown in Table 4 and 5, straw management and tillage options influenced significantly among the treatments regarding the yield and yield components of wheat. Maximum grain yield (4.38 and 4.41 t/ha) was found from 30% straw with fresh bed systems in both years (2011-12) and minimum (3.87 and 3.82 t/ha) was obtained from 0% straw retention with conventional method (Table 5). Maximum grains/spike (52.4) was obtained from 30% straw retention with PB and minimum (48.2) was found from 0% straw retention with conventional tillage option (Table 4). The results indicate that 30% straw management has been profoundly recorded to be involved in enhancing the different yield characteristics

Table 4. Interaction effect of tillage options and straw management on mean grain yield attributes of wheat in 2010-2011 and 2011-2012

Tillage options × Straw management	Spikes/m ²	Spikelets/spike	Grains/spike	TGW (g)
Conv × 0 % Straw	311	17.2	48.2	53.5
Conv × 30 % Straw	329	18.7	51.5	54.7
PB × 0 % Straw	317	17.7	48.4	53.4
PB × 30 % Straw	321	18.7	52.4	54.5
FB × 0 % Straw	319	17.8	49.2	52.6
FB × 30 % Straw	325	18.4	52.3	54.2
CV (%)	11.34	5.34	7.59	3.65
LSD (0.05)	13.25	NS	0.231	1.075

Table 5. Interaction effect of tillage options and straw management on grain yield of wheat in 2010-2011 and 2011-2012

Tillage options × straw management	Grain yield (t/ha)	
	2010-11	2011-12
Conv × 0 % Straw	3.87	3.82
Conv × 30 % Straw	4.04	4.25
PB × 0 % Straw	4.24	4.04
PB × 30 % Straw	4.31	4.27
FB × 0 % Straw	4.21	4.24
FB × 30 % Straw	4.38	4.41
CV (%)	12.44	5.65
LSD (0.05)	0.473	0.514

in different tillage options. Mohammed *et al.* (2007) found that the burning of straw increases nutrient availability on the short term. Rather than the retention of crop residue as such, the combination of crop residue retention and tillage will induce a change in the nitrogen cycle and as such the timing of N release (Govaerts *et al.*, 2006). Therefore, there is a co-relation between the alterations of different tillage and the crop residue such as straw management.

Interaction effect of tillage options and N fertilization.

Grains/spike and TGW were highly significant by the interaction effect of tillage options and N levels except spike/m² and spikelets/spike (Table 6). Maximum grains/spike (54.4) was found from fresh bed with 120% N application. Statistically similar spike/m² (54.0) and (53.2) were also found from fresh bed with 100% and 80% N application. Table 7 shows the effect of different tillage options as well as N-levels on grain yield of wheat. Grain yield was highly significant by the interaction effect of these factors. The highest grain yield (4.45 and 4.58 t/ha) was obtained from fresh bed system with 120% nitrogen application both the years. Statistically similar yield (4.62 t/ha), (4.12 t/ha) were obtained from the interaction effect of permanent bed with 120% nitrogen application. The lowest yield (3.57 and 3.68 t/ha) were also found from conventional planting with 80% N application. It is assumed that management of fertilization and involvement of tillage is a major approach for the improvement of wheat production and growth. Properly applied nitrogen fertilizer has a positive effect on crop yield. The long-term influence of fertilizers on crop production in the northern great plains has been researched in some of

Table 6. Interaction effect of tillage options × N-levels on mean yield components of wheat during 2010-11 and 2011-2012

Tillage options × N levels	Spikes/m ²	Spikelets/spike	Grains/spike	TGW (g)
Conv × 80 % N	315	17.2	48.6	53.2
Conv × 100 % N	317	17.6	49.2	53.3
Conv × 120 % N	337	17.2	49.4	54.4
PB × 80 % N	311	17.9	51.5	53.2
PB × 100 % N	314	18.3	52.4	56.4
PB × 120 % N	322	18.2	52.6	55.2
FB × 80 % N	318	17.8	53.2	53.6
FB × 100 % N	321	18.3	54.0	55.2
FB × 120 % N	330	18.8	54.4	55.1
CV (%)	13.14	5.34	7.59	3.65
LSD (0.05)	NS	NS	0.231	1.023

Table 7. Interaction effect of tillage options × N-levels on yield of wheat during 2010-11 and 2011-12

Tillage options × N levels	Grain yield (t/ha)	
	2010-11	2011-12
Conv × 80 % N	3.57	3.68
Conv × 100 % N	3.82	3.95
Conv × 120 % N	4.04	4.32
PB × 80 % N	3.84	3.97
PB × 100 % N	4.03	4.43
PB × 120 % N	4.12	4.62
FB × 80 % N	3.97	3.67
FB × 100 % N	4.18	4.40
FB × 120 % N	4.45	4.58
CV (%)	12.44	9.96
LSD (0.05)	0.473	0.575

the studies (Campbell *et al.*, 2005). Most studies have demonstrated the need for and benefit of, applying adequate fertilizers to achieve optimum economic returns (Zentner *et al.*, 2007; Campbell *et al.*, 1990).

Conclusion

In the ongoing study, fresh bed with 120% N application was found maximum grain yield but statistically similar yields were also found from fresh bed and permanent bed with 100 and 120% N application. It was also similar with conventional tillage practice (CTP) with 120% nitrogen application. The higher grain yield, total grain weight and other yield components were found to be higher for fresh bed rather than conventional or permanent cropping systems. The strategy applied in enhancing the wheat yield may give an insight in development of wheat cultivation in Bangladesh. Consequently, there is need to conduct long term experiments so as to make appropriate measurements and assessments of the influence of such recommended management practices on sustainable production.

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