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# EFFECT OF DIFFERENT TILLAGE OPTIONS AND RESIDUE RETENTION FOR SUSTAINABLE CROP PRODUCTION IN WHEAT-MUNGBEAN-RICE CROPPING PATTERN IN DRY AREAS

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## Abstract

The study was conducted to know the productivity and soil fertility status of intensified rice-wheat (RW) systems by adding a third pre-rice crop mungbeani.ewheat-mungbean-rice cropping pattern. The trial comprises five packages of practices including crop residue retention, seeding methods with tillage options imposed on the component crops in the same cropping pattern. The results indicated that keeping standing 30% crop residue in the field with minimum disturbance of soil had significant contribution on grain yield of wheat-mungbean-rice sequence compare to conventional practice of well-till without crop residue retention. System productivity and fertility were evaluated under five levels of tillage options (zero, strip, raised bed, minimum tillage by power tiller operated system (PTOS) and conventional tillage practice (CTP) in a RWM cropping pattern. Both permanent raised bed and strip till with 30% straw retention produced the highest productivity in all years and the lowest yield was also found from conventional practice with 30% straw retention.Soil organic matter in surface soil had increased by 0.12% after 3years crop cycles with 30% SR from rice and wheat and full residue retention from mungbean crop. Straw retention is an important component of soil management and may have long term positive impacts on soil quality. The combination of raised bedsystems and strip tillage with 30% residues retained appears to be a very promising technology for sustainable intensification of wheat-mungbean-rice croppingpattern in dry zone areas.

## Introduction

Resource conserving technologies (RCT) are being introduced to the farmers and they are showing interest to grow crop with RCT because, it reduces cultivation cost, protects degradation of soil and saves water without yield sacrifice. Zero-till, bed planting, strip tillage and minimum tillage by power tiller operated seeder (PTOS) with residue retention are known as Resource conservation technology (RCT). RCT also offers the opportunity to plant wheat timely (Lauren*et al.,* 2006). Delayed wheat planting reduces yield @ 1.3% per day after November 30. Connor *et al.* (2002) suggested that permanent raised beds might offer farmers further significant advantages such as increased opportunities for crop diversification, mechanical weeding and placement of fertilizers. However, for getting expected crop yields with RCT a full package of production technologies especially fertilizer management should be included. Although the non-rice season across the rice-wheat area with low rainfall, heavy pre-monsoonal rain can cause disastrous effects on the third crop, like maize or mungbean grown after wheat or before rice, both during establishment and grain filling stagedue to water logging (Timsina and Connor, 2001; Quayyum*et al.*, 2002). Broadcasting fertilizer enhances losses of fertilizer and reduces fertilizer use efficiency in RCT tillage options especially in zero-till and bed planting practices. On the other hand, there are many evidences that residue retention have significant contribution on crop productivity and soil fertility with sustainable way. Growing maize crops in a cropping system is beneficial not only for economic products but also for soil amelioration (Singh,2003). The research work on residue management with RCT is not done on large scale in our country. So, in the experiment it was tried to find out the sustainable yield from the pattern wheat-monsoon riceby introducing third crop mungbean after wheat and to improve soil fertility and productivity.

## Materials and Methods

A rabi season wheat (*Triticumaestivum*)-kharif 1 mungbean (*Vignaradiata*)-monsoon rice(*Oryza sativa*) cropping pattern was started instead of wheat-monsoon rice pattern with wheat sown in November 24, 2015 at the Regional Wheat Research Centre, Shyampur, Rajshahi, Bangladesh (24$^{o}$3'N, 88$^{0}$41E, 18 m above sea level). The site has a subtropical climate and is located in Bangladesh Agro Ecological Zone 11 (High Ganges River Flood Plan) on flood-free high land, with coarse-textured, highly permeable soil (BARC, 2012). The area generally receives 1072 mm mean annual rainfall, about 95% of which occurs from May to September. Total rainfall was the highest during the monsoon rice season and lowest in the wheat season in all years. Sometime maximum temperature was above 38-40$^{0}$C in the month of May and minimum temperature was below 3-5$^{0}$C in the month of January. Sunshine hours were maximum during the month from November to March in every all year (Figure 1).

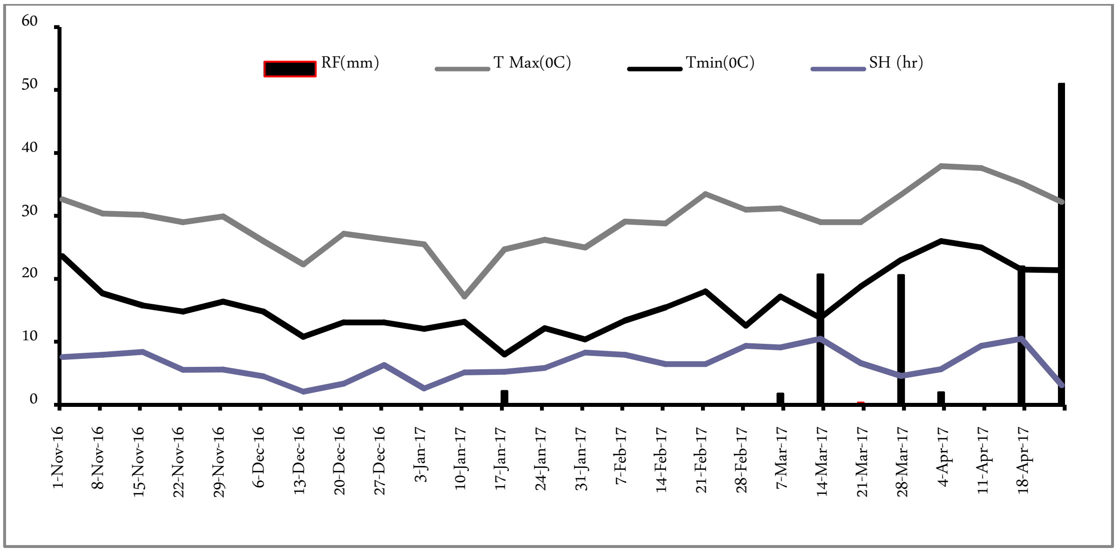


Fig. 1. Weekly weather parameters from all crop season.

The trial involved a three-crop sequence i, e., rice-wheat-mungbean (RWM) planted on zero, tillage, strip tillage, and permanent raised bed, minimum tillage and conventional practices. Rice was transplanted (one 25-days-old seedling per hill) with spacing 30 cmx 15 cm spacing in late July and harvested in late November by manual. Wheat was seeded with 100-120 kg seed ha$^{-1}$withfive tillage like zero tillage, strip tillage, permanent raised bed, minimum tillage and conventional practice, respectively, in late November and harvested in late March. After harvest of wheat, mungbean was sown in early April with seeding rate of 35 kg ha$^{-1}$ and harvested in mid-July for zero tillage, strip tillage, permanent raised bed, minimum tillage and conventional practices. The trial was established in the treatments of five tillage options with 30% straw (1.5 t $ha^{-1}$) management practices. The area of each subplot was 15 $m^2$ (5m x 3m) with three replications. After planting the wheat or rice, straw from the preceding cereal crops was returned as mulch into the plot from which it had been removed at harvest. After harvesting and threshing, the rice and wheat straw were returned without chopping as standing way.

The width of the beds was 60 cm (furrow to furrow) and the depth of the furrows on average was 15 cm. Two rows of wheat (var. BARI Gom-30) or rice (var. BRRI dhan71) with a spacing of 30 cm, were planted by hand sowing on each tillage options, two rows of rice on zero tillage, strip tillage, permanent raised bed, minimum tillage and conventional method, Mungbean (var. BARI Mung-6) was sown by tillage machineries in the furrows and indicator plant to assess microbial activity in the soil environment. The mungbean was harvested about 60 days after sowing (DAS). In case of conventional tillage practices (CTP), wheat was sown in 20 cm, mungbeanwassown in 30 cm and rice was transplanted in 30 cm x 15 cm spacing. A basal dose of P (20, 22 and 26 $kgha^{-1}$) from triple super phosphate, K (15, 35 and 33 $kgha^{-1}$) from muriate of potash and S (10, 11 and 20 $kgha^{-1}$) from gypsum was applied to mungbean, rice and wheat, respectively. In rice, the entire amount of PKS was broadcast before transplanting and mulching on zero tillage, strip tillage, permanent raised bed, minimum tillage and conventional tillage practice (CTP). For CTP the fertilizer was broadcast before tillage as is the usual practice. The recommended rate of N (80 $kgha^{-1}$ for rice, 100 $kgha^{-1}$ for wheat and 20 $kgha^{-1}$ for mungbean) was applied as urea. For mungbean all N was applied before seeding. With CTP, N was applied in broadcast, while with beds it was banded on top of the soil between two rows in three equal installments 15, 30 and 45 days after seeding, while wheat, two-thirds of the N was applied before seeding and the remaining one-third at crown root initiation (CRI) stage.

Sufficient irrigation water was applied to fill the furrows of all tillage options.Flood irrigation was applied in conventional plots. Weed control was done after the first irrigation for wheat by affinity application @ 2 $glitre^{-1}$ of water, and at 25 and 45 days after transplanting for rice by Ronstar @ 1$mllitre^{-1}$ of water. It is important to note that there was no additional weeding where outbreaks occurred-the treatments were compared with the same level of weed management. Grain and straw yield were determined on a whole plot basis or 15 $m^2$ areas in each plot.

**Statistical analysis of data**

The data were analyzed statistically following computer package MSTATC and the significance of mean differences was adjudged by Duncan's Multiple Range Test (DMRT) at $P \leq 0.05$ (Gomez and Gomez, 1984).

## Result and Discussion

Before experimentation initial soil sample (before 1st crop) was collected and analyzed to know the nutrient status and the results were presented in Table 1. The soil was slightly alkaline (7.8 pH) having low organic matter content (0.94%) and the total N & boron content was very low (0.05% & 0.27 µg). The overall soil fertility status was low.

Table 1. Fertility status of initial soil sample of the experimental site at RWRC, BARI, Rajshahi before started the experiment

| Sample | pH | OM (%) | Total N (%) | K<br>$Meq100g^{-1}$ | P | S | Zn<br>$\mu g\ g^{-1}$ | B |
|---|---|---|---|---|---|---|---|---|
| Value | 7.8 | 0.94 | 0.05 | 0.21 | 10 | 23.3 | 0.14 | 0.27 |
| Critical level | - | - | 0.12 | 0.12 | 10 | 10.0 | 0.60 | 0.20 |

| Interpretation | Slightly Alkaline | Very low | Very low | Medium | Low | Opt. | Very low | Very low |
|---|---|---|---|---|---|---|---|---|

## Grain yield and yield components of wheat

Yield and yield components data were shown in Table 2. Tillage systems with straw retention had significant influenced on grain yield and yield components except spike $m^{-2}$ and spikeletspike$^{-1}$. The maximum average grain yield 4.39 t $ha^{-1}$ from raised bed systems with 30% straw retention and same yield were also found from strip till method 4.28 t $ha^{-1}$. The lowest yield 3.79 t $ha^{-1}$was also found from conventional tillage with 30% straw retention. Grain yield was higher due to higher yield attributes. Lauren*et al.* (2006) got higher yield from both permanent bed and strip till method. The minimum yield (3.79 t $ha^{-1}$) was found from conventional tillage practice due to lower yield components.Kataki (2001) found similar findings from both tillage options in wheat.

Yield components like spike $m^{-2}$ and spikelet spike$^{-1}$ did not get any significant effect on different tillage options but other attributes like grains spike$^{-1}$and thousand grain weight (TGW) were also significant effect on tillage options with straw retention. Maximum grains spike$^{-1}$ was found from raised bed system and at par with strip tillage method and minimum grains spike$^{-1}$ was also found from conventional tillage. Sayre *et al.*(2005) found maximum yield components from residue retention with raised bed and strip till method.

Table 2.Yield and yield components of wheat as influenced by different tillage options and strawretention in 2015-16 to 2016-17

| Tillage options x Straw retention | Spikes $m^{-2}$ (no.) | Spikelet spike$^{-1}$ (no.) | Grains spike$^{-1}$ (no.) | TGW (g) | Grain yield (t $ha^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | | | | 2015-16 | 2016-17 | Average |
| Conv. x 30% straw | 322 | 17.7 | 48.3 | 52.4 | 3.73 | 3.85 | 3.79 |
| Xerox 30% straw | 317 | 18.3 | 49.2 | 53.6 | 4.08 | 4.19 | 4.14 |
| Strip x 30% straw | 319 | 18.5 | 50.3 | 53.8 | 4.24 | 4.32 | 4.28 |
| Bed x 30% straw | 312 | 18.6 | 51.4 | 54.2 | 4.36 | 4.41 | 4.39 |
| PTOS x 30% straw | 325 | 18.2 | 49.8 | 52.8 | 4.04 | 4.02 | 4.03 |
| CV (%) | 9.76 | 6.85 | 8.45 | 5.75 | 10.25 | 7.65 | - |
| $LSD_{(0.05)}$ | ns | ns | 1.325 | 1.024 | 0.245 | 0.413 | - |

### Plant height and biomass production ofmungbean crop

Both biomass productions and plant height were significantly influence under different tillage options with 30% straw retention Table 3). The higher plant height (77.4 cm) from raised bed with 30% straw retention and it was at par with zero tillage with 30% straw retention. Maximum fresh biomass weight (20.2 t $ha^{-1}$) was found from raised bed tillage system followed by zero tillage (19.3 t $ha^{-1}$) and strip till method. The two years average oven dry biomass yield (3.85t $ha^{-1}$) was also found from raised bed system and it were zero (3.76 t $ha^{-1}$) and strip till (3.62t $ha^{-1}$) method. Sayre *et al.* (2005) found similar findings from their experiments under permanent and zero tillage system.

Table 3.Plant height and freshbiomass at 40 DAS with two years dry biomassproduction at finalharvest of mungbeanat different tillage options with straw retentionin 2015-16 and 2016-17

| Tillage options | Plant height (cm) | Fresh biomass yield (t $ha^{-1}$) | Dry biomass yield (t$ha^{-1}$) | | |
|---|---|---|---|---|---|
| | | | 2015-16 | 2016-17 | Average |
| Zero tillage | 76.3 | 19.3 | 3.72 | 3.80 | 3.76 |
| Strip tillage | 72.6 | 18.5 | 3.58 | 3.66 | 3.62 |
| Raised bed | 77.4 | 20.2 | 3.77 | 3.93 | 3.85 |

| | | | | | |
|---|---|---|---|---|---|
| Minimum tillage | 73.5 | 17.2 | 3.43 | 3.53 | 3.48 |
| Conventional | 68.2 | 16.4 | 3.27 | 3.37 | 3.32 |
| $LSD_{(0.05)}$ | 5.75 | 1.112 | 0.348 | 0.360 | - |
| CV (%) | 14.52 | 10.56 | 10.35 | 10.23 | - |

Despite lower grain yields were also found from zero tillage mungbean always produced higher biomass with taller plants than in conventional tillage and followed by raised bed systems. It might be an indirect benefit for soil in zero tillage and raised bed planting methods. For excessive vegetative growth in mungbean in zero tillage might reduce the grain yields. Lemon Ortega *et al*. (2004) found maximum biomass from raised bed and zero tillage systems.

**Seed yield and yield components of mungbean**

Conservation agriculture influenced by different characters of mungbean. Consequently, pod plant$^{-1}$, seeds pod$^{-1}$, 1000 seed weight and seed yield were influenced significantly whereas plants m$^{-2}$ was statistically insignificant (Table 4). The maximum pods plant$^{-1}$ was recorded in raised bed with 30% straw retention (22.3) which was statistically identical with that of strip and minimum tillage with 30% straw retention. Talukder*et al*. (2004) found maximum munbean yield from both raised bed and strip till method.The minimum pods plant$^{-1}$ was found from conventional with 30% straw retention. Similarly, maximum seedspod$^{-1}$, 1000 seed weight and seed yield were recorded from both raised bed and strip till with 30% straw retention. This might be due to border effect with more uptakes of nutrients. 26% yield increased from raised bed with 30% straw retention and it was identical of strip and minimum tillage. Zero tillage did not give higher yield increase but it was higher from conventional with 30% straw retention.Talukder*et al*. (2006) found more pods plant$^{-1}$ and seeds pod$^{-1}$from both permanent and strip tillage systems.

Table 4.Average two years yield and yield components of mungbean as influenced by different tillage options and straw retention from 2015-16 and 2016-17

| Tillage options x Straw retention | Plant stands m$^{-2}$ (no.) | Pods plant$^{-1}$ (no.) | Seeds pod$^{-1}$ (no.) | TSW (g) | Av. two years seed yield (tha$^{-1}$) | (%) Yield increase over conv. |
|---|---|---|---|---|---|---|
| Conv. x 30% straw | 38.5 | 17.8 | 7.87 | 50.8 | 1.02 | - |
| Zero x 30% straw | 37.8 | 18.5 | 8.70 | 51.2 | 1.12 | 8.0 |
| Strip x 30% straw | 39.2 | 21.7 | 9.12 | 52.0 | 1.25 | 18.0 |
| Bed x 30% straw | 38.9 | 22.3 | 10.24 | 52.4 | 1.37 | 26.0 |
| PTOS x 30% straw | 39.3 | 21.4 | 9.04 | 50.3 | 1.21 | 15.0 |
| CV (%) | 11.63 | 10.42 | 3.48 | 2.32 | 3.47 | - |
| $LSD_{(0.05)}$ | ns | 3.24 | 0.595 | 0.892 | 0.213 | - |

ns; *f*-test was not significant

**Grain yield and yield components of T.Aman (monsoon) rice**

Conservation agriculture influenced by different characters of T. Aman rice. Consequently, grains panicle$^{-1}$ and 1000 grain weight were influenced significantly whereas hill m$^{-2}$, panicles hill$^{-1}$ and grain yield were statistically insignificant (Table 5). The maximum grains panicle$^{-1}$(133.8) was recorded in raised bed with 30% straw retention which was statistically identical (127.2 & 124.6) with that of strip and PTOS with 30% straw retention. Singh *et al.* (2005) found non-significant effect of rice under different tillage options with residue retention about four years. The minimum grains panicle$^{-1}$ (122.4) was found from zero tillage with 30% straw retention and it was identical with conventional with 30% straw retention. Similarly highest 1000 grain weight (25.2 g) was recorded from both raised bed and strip till (24.8 g) with 30% straw retention. Gupta*et al.*(2002) found similar findings from their experiments. Average two years maximum grain yield was recorded (4.53 t ha$^{-1}$) from raised bed systems and it was identical with that of strip till (4.47 t ha$^{-1}$) and minimum tillage by PTOS (4.41 t ha$^{-}$

[1]) with 30% straw retention. The average minimum grain yield (4.23 t ha$^{-1}$) from zero tillage option.Quayyum*et al.*(2002) obtained similar results from their experiment.

Table 5.Average two years yield and yield components of T.Aman rice as influenced by different tillage options and strawretention from 2015-16 and 2016-17

| Tillage options x Straw retention | Hill m$^{-2}$ (no.) | Panicles hill$^{-1}$ (no.) | Grains panicle$^{-1}$ (no.) | TGW (g) | Grain yield (t ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|
| | | | | | 2015-16 | 2016-17 | Average |
| Conv. x 30% straw | 28.7 | 18.1 | 126.8 | 23.8 | 4.26 | 4.41 | 4.34 |
| Zero x 30% straw | 27.5 | 17.7 | 122.4 | 23.7 | 4.19 | 4.27 | 4.23 |
| Strip x 30% straw | 29.5 | 19.2 | 127.2 | 24.8 | 4.41 | 4.53 | 4.47 |
| Bed x 30% straw | 29.8 | 19.4 | 133.8 | 25.2 | 4.43 | 4.63 | 4.53 |
| PTOS x 30% straw | 28.7 | 18.2 | 124.6 | 23.7 | 4.33 | 4.49 | 4.41 |
| CV (%) | 9.76 | 6.85 | 8.45 | 5.75 | 10.87 | 9.56 | - |
| $LSD_{(0.05)}$ | ns | ns | 0.325 | 0.422 | ns | ns | - |

Labor requirement and % saved labor for land preparation with seeding or transplanting

From three years study both from Resource conservation technologies (RCTs) and conventional tillage practices, we found from Table 6 that conventional tillage required more number of labor for land preparation with seeding and transplanting of wheat and rice seedlings over RCTs. Connor*et al.*(2002) found similar findings from same type of tillage experiments. Beside this, from figure 2it observed that RCTs (ZT, BP, ST) tillage saved 26-50% labor under land preparation. Bed planting, zero tillage and strip tillage saved labor from 50%, 28%, 26%, respectively.Kataki*et al.*(2001) obtained 25-35% labor saving from raised bed and strip tillage systems.

Table 6. Labor requirement and save labor for land preparation and seeding/transplanting of wheat and rice crop

| Tillage options | Year 1 | Year 2 | Year 3 | Average | Save labor (person hr$^{-1}$ ha$^{-1}$) |
|---|---|---|---|---|---|
| RCTs | 376 | 316 | 409 | 367 | 126 |
| CTP | 503 | 450 | 526 | 493 | - |


Fig.2. Saved labor (%) from land preparation with seedingof wheat crop under different tillage options (CT-Conventional tillage, ZT-Zero tillage, BP-Bed planting, ST-Strip tillage).

**Soil properties**

After 3 years crop cycles both from raised bed and strip tillage options that of soil condition was improved over conventional tillage practice (Table 7). Soil pH, organic matter content, total N, available P, exchangeable K and Mg were found higher in both raised bed and strip tillage options than conventional tillage. After 3 years crop cycles, retention of straw from all three crops in all tillage systems had increased the soil organic matter by 0.08-0.12% over conventional. Since the all tillage options produced more biomass in mungbean and higher crop residues were kept in the soil, properties were improved. Hobbs *et al.*(2000) found more biomass in permanent raised bed with straw retention experiments. While some of the increment may have been due to formation of the beds from topsoil, the change in organic C increased as the rate of residue retention increased from 100%, indicating that straw retention also increased organic C on the beds. Kumar and Goh (2000) reported that, in the longer term, residues and untilled roots from crops can contribute to the formation of SOM. After three years crop cycles, soil condition in permanent raised bed tillage options was better than conventional tillage.

Table 7. Soil properties analyzed after three years crop cycle

| Tillage options X SR | pH | Organic matter (%) | Total N (%) | Available P ($\mu$g g$^{-1}$soil) | Exchangeable K (meq100g$^{-1}$ soil) | Available S (*m*g g$^{-1}$ soil) | Zn ($\mu$gg$^{-1}$ soil) | B ($\mu$g g$^{-1}$ soil) |
|---|---|---|---|---|---|---|---|---|
| Conv. x 30% SR | 7.9 | 1.02 | 0.06 | 13.3 | 0.23 | 23.7 | 0.15 | 0.29 |
| Zero x 30% SR | 8.0 | 1.04 | 0.07 | 13.5 | 0.25 | 24.2 | 0.17 | 0.31 |
| Strip x 30% SR | 8.2 | 1.05 | 0.07 | 14.5 | 0.25 | 24.8 | 0.18 | 0.34 |
| Bed x 30% SR | 8.1 | 1.06 | 0.08 | 14.2 | 0.27 | 24.9 | 0.19 | 0.35 |
| PTOS x 30% SR | 8.2 | 1.04 | 0.08 | 13.8 | 0.26 | 24.8 | 0.18 | 0.34 |

## Conclusion

Yield and yield component of crops with an intensive wheat-mungbean-rice cropping pattern was achieved more under different tillage options with 30% straw retention over conventional. From two years study it was revealed that raised bed and strip tillage systems with 30% straw retention affected in terms of yield and yield components for all three crops which ultimately produced maximum yield due to its more border effect. Soil organic matter in surface soil had increased by 0.12% after two years crop cycles with 30% residue retention from rice, wheat and full residue retention from mungbean crop. Residue retention is an important component of soil management and may have long term positive impacts on soil quality. Both raised bed and strip till systems with 30% residues retained appears to be a very promising technology for sustainable intensification of rice-wheat-mungbean (RWM) systems in dry areas.

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