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Research Article

Strip planted mechanical seeding of mustard and mungbean with crop residue retention is more profitable than conventional practice

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Abstract

Smallholder agriculture of the Asian continent faces a significant challenge of declining soil productivity and an acute shortage of agricultural labor. Reduced tillage and crop residue mulch application is an integrated approach to preserving soil health and addressing the labor crisis to maintain farm sustainability. We undertook this study to evaluate the effect of strip planting and increased residue mulching on mustard and mungbean's productivity and profitability in northern Bangladesh during 2015 and 2016. Mustard cv. *BARI Sharisha 14* and mungbean cv. *BARI Mungbean 6* was grown following (i) Conventionally Tilled broadcasting method (CT) and (ii) Strip Planted line seeding (SP) with two levels of crop mulch (i) no-mulch and (ii) 50% mulch. The CT was done by a two-wheel tractor with four plowings and cross plowing followed by leveling. In SP, single tillage, seeding, fertigation, and field leveling were done simultaneously by a Versatile Multi-crop Planter machine. Results reveal that mechanized seeding of mustard and mungbean in SP with 50% residue mulching fetched 62% higher profit than broadcasted CT without residue through producing 24% higher seed yield. This practice reduced the land preparation costs by 68%, in association with reducing the labor and fuel requirements by 30%. Hence, it could be concluded that the mechanized seeding of mustard and mungbean with the retention of 50% of crop residue is profitable to the conventionally broadcasted seeding process.

Introduction

Recent tillage is mostly traditional and highly mechanized. This Conventional Tillage (CT) has been accused of soil erosion, decrease soil fertility, severe water loss, labor and time-consuming, and increasingly worse ecological environment (Eshete et al., 2020). During this global crisis era, it is high time to avoid power tiller-based CT, and Reduced Tillage (RT) might be an appropriate alternative for improving

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soil health, crop yields, and financial and ecological advantages. The economic uses of irrigation water, fuel, and labor for sustainable agricultural production are getting crucial. The RT consumes less water by conserving soil moisture, less energy by reducing tillage passes, and less labor through mechanized planting and cultural practices (Kassam et al., 2019). Ultimately, the costs of production lessen in RT than CT, making this practice more profitable, appealing RT for worldwide adoption (Colecchia et al., 2015). In Bangladesh, RT-based crop production could also be utilized relative to power tiller-based CT. Among the several tilling options for RT, Strip Planting (SP) is one (Johansen et al., 2012) that utilizes 15-25% soil disturbance for making strips of 6 cm deep and 4-6 cm wide (Haque et al., 2017).

Mustard and mungbean are the most important oil and pulse crop, respectively, in Bangladesh. These are considered the major crops of the respective category for their beneficial effect on soil fertility, improving system productivity, farm income, and dietary safety (Dainavizadeh & Mehranzadeh, 2013; Miah et al., 2015). These short-duration crops (85 and 65 days, respectively) can easily fit in rice-based cropping systems. But Bangladesh is facing an acute shortage of these two crops due to low yield and less acreage. After rainfall, excessive soil moisture cannot permit a tractor or any deep tillage device to prepare the soil for seeding these crops. Besides, agricultural labor scarcity is also causing delayed sowing. As a result, mustard and mungbean cannot be planted in due time in mid-November and mid-March, respectively. The inverse climate leads to fall diseases and finally yield loss. It is essential to introduce new seeding technologies that overcome management problems (e.g., wet soil from previous cultures, labor scarcity) for low yields.

Among the recently introduced different direct seeding technologies in Bangladesh, Strip Planting (SP) is one example. The SP has reported mitigating excess soil moisture problems at sowing time, agricultural labor scarcity, late sowing, abuse of costly fossil fuel, and emission of CO_2 directly or indirectly. Research reports available in Bangladesh (Hossain et al., 2015; Rahman et al., 2016) revealed that oilseeds and pulses could be established and grown successfully through SP with the retention of previous crops' residues as a component of Conservation Agriculture (CA) technology. This technology is more viable in drought stress areas. Seeding operation and initial plant establishment can be done utilizing the residual soil moisture available immediately after monsoon rice and wheat harvest (Zaman & Islam, 2020). Therefore, this study undertook to determine SP-based mechanical seeding's performance plus the retention of the straw of previous rice and wheat to improve mustard and mungbean performance.

Materials and methods

Experimental site and season

This on-farm experiment was conducted at the farmers' field located at Durbachara village of Bhangnamari union, situated at Gouripur sub-district under Mymensingh district of Bangladesh, geographically at 24˚75'N and 90˚50'E, at 18 m altitude. This study was carried out during November-February in 2015 and March-May in 2016.

The edaphic and climatic environments

The experiment site is situated on the Old Brahmaputra Floodplain of predominantly dark grey non-calcareous alluvium soils under the *Sonatala* series. The experimental field was flood-free medium-high land, and the soil texture was sandy clay loam (50% sand, 23% silt, 27% clay), having pH 7.2.

During the mustard season (November 2015 – February 2016), the highest maximum and minimum temperatures (29.9 and 18.07 ℃, respectively) prevailed in November followed by February (Figure 1). Temperature declined towards January, making this month the coldest. The highest rainfall (20 mm) was taped in February, but November was the driest with the longest sunshine hours. The minimum sunshine hours was found in December.

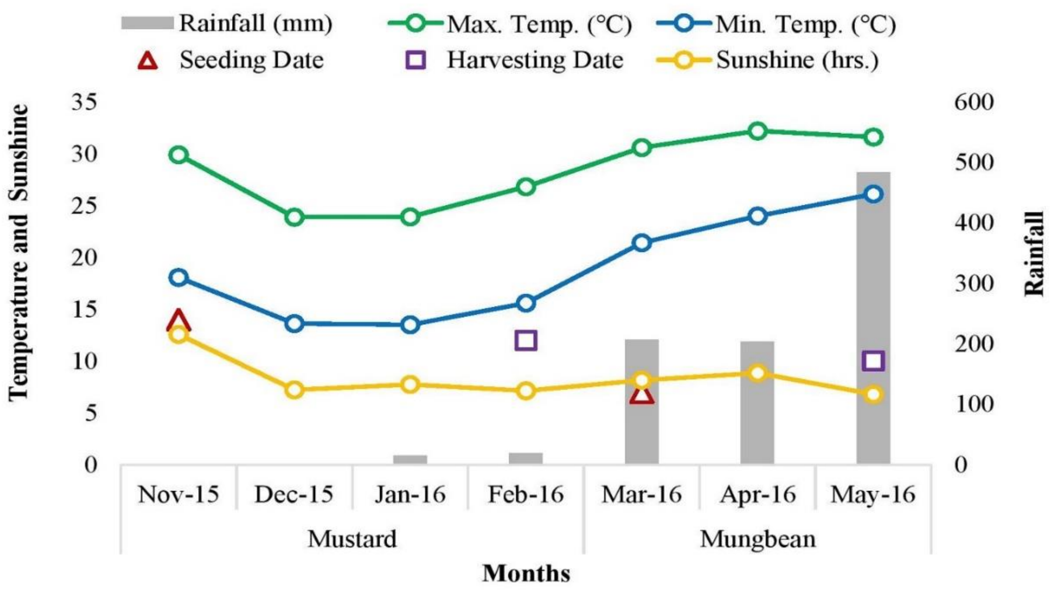

Figure 1. Monthly climatic distribution pattern during mustard and mungbean growing season at Gouripur, Bangladesh in 2015–2016

During the mungbean growing period (March – May 2016), the highest maximum and minimum heats (32.2 and 26.1 °C, respectively) were transcribed in April. May had the most increased precipitation (484 mm), followed by March and April. The highest and lowest sunshine hours were recorded in March and May, respectively.

Experimental treatments and design

The present study deals with mustard cv. *BARI Sharisha 14* and mungbean cv. *BARI Mungbean 6* were cultivated utilizing conventionally tilled broadcasted seeding (CT) vs. strip planted line seeding (SP) in non-mulched (M_0) vs. 50% mulched (M_{50}) in each 9 m × 5 m plot. A randomized complete block design having four replications was followed to accommodate all treatments.

Crop cultivation practices

We used a two-wheel tractor (2WT) for CT, where four plowings prepared to land and cross plowings, afterward sun-drying for two days and leveling. Alternatively, Versatile Multi-crop Planter (VMP) machine did the SP in a single plowing process making four furrows, each 6 cm wide and 5 cm deep at a time. As per recommendation, to destroy the live weeds, glyphosate herbicide (3.7 L ha^{-1}) had sprayed at three days before the VMP operation (Haque et al., 2017).

Seven and 30-kilogram seeds ha^{-1} of mustard and mungbean sown on November 14 and March 7, respectively. In CT, seeds were broadcasted, but in SP, the VMP did the continuous seeding at 20 cm apart and covered the seeds concurrently.

Two levels of straw mulch of monsoon rice in mustard and wheat in mungbean were used. Plots were kept bald, short of straw in no-mulch practice. On the other hand, the monsoon rice and wheat were harvested at 50% of plants standing in 50% mulch practice.

Cultural operations

Mustard and mungbean were fertilized (ha^{-1} basis) with 60 & 20 kg N, 40 & 20 kg P_2O_5, 30 & 15 kg K_2O, and 15 &10 kg S as a basal dose, respectively. The required amount of N, P, K, and S was supplied through urea, Di-Ammonium Phosphate (DAP), Muriate of Potash (MoP), and gypsum, respectively. The urea and DAP were applied in strips using VMP simultaneously at seeding time in SP. We followed the recommended cultural practices and plant protection measures were to raise a healthy crop.

Measurements

We harvested crops at 80% of maturity on February 12 and May 10, respectively. In each plot, three bits 3 m × 1 m area was selected randomly. We recorded plant population, the number of pods plant^{-1}, and the pod's length from ten plants prior to crop reaping. The 1000-seeds weight and seeds yield were adjusted at 14% moisture content, and percent yield and Benefit Cost Ratio (BCR) increase over control (YOC) was calculated using the formula -

$$YOC\,(\%) = \frac{T-C}{C} \times 100$$

Where C and T are the yield and BCR in control and treatments, respectively.

The costs incurred for crop production were calculated based on the labor needs for seeding to harvest and costs for tillage, seeds, fertilizers, irrigations, pesticides, etc. The total income was processed based on the selling price of seeds and derivatives. Finally, we calculated the benefits by measuring the ratio of total revenue to the total costs incurred.

Statistical analysis

We used *STAR* software to analyze all data following the standard procedure of Analysis of Variance and Duncans' Multiple Range Test at $p \leq 0.05$.

Results and discussion

Effect on the yield

The interaction among tillage types and mulching levels exerted a significant effect ($p \leq 0.05$) on the number of pod m^{-2} and seed yield (t ha^{-1}) (Figure 2) except the plant population m^{-2}, length of pod, and weight of 1000-seeds (data not shown) both of mustard and mungbean. The highest seed yield was recorded in SP with 50% mulch, followed by SP without mulch and CT with 50% or without mulch. Although the effect of treatments on the plant population was statistically non-significant, numerically, 7% higher plant population (data not shown) was found in the SP with 50% crop residue. The higher plant population in SP might happen due to better moisture and ambient soil temperature preservation, which is essential for better seed germination of mustard and mungbean. About 24% higher yield in SP than CT was associated with the 7% higher plant population, 6% higher number of pods m^{-2} area. Retaining 50% mulch generated 3% more pods, leading to a 5% higher amount of seeds than no-mulch.

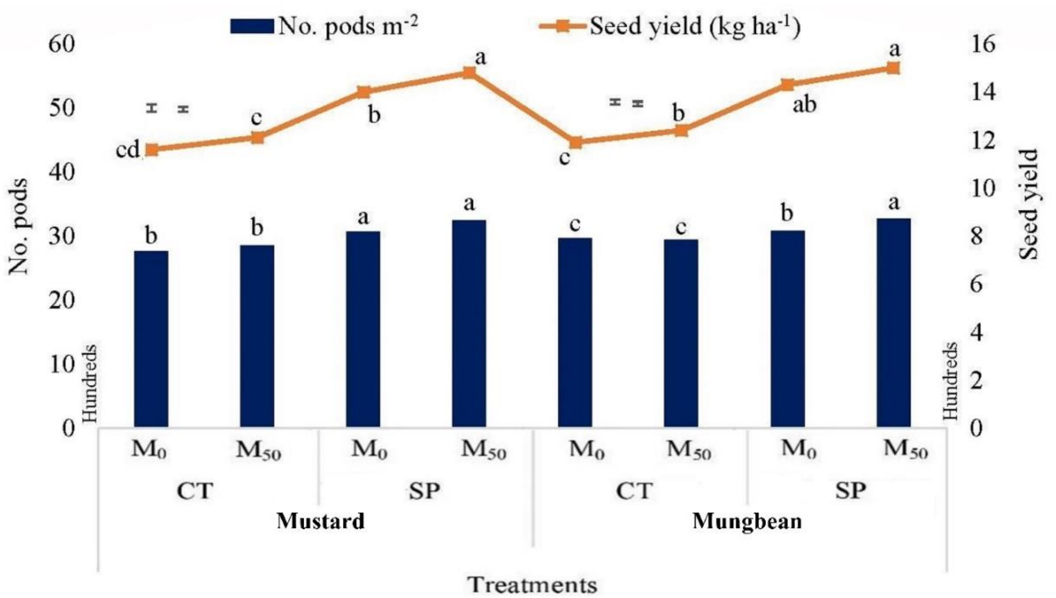

Figure 2. The combined effect of tillage and mulch on the number of pods and seed yield of mustard and mungbean. Means with the similar letter did not vary significantly at p≤0.05

The higher yield in SP might have attributed to the changes in soil properties *viz.* the higher porosity and better soil moisture conservation in SP favored the more robust root growth and nutrient uptake resulted in increasing seed yield of mustard and mungbean. These results agree Huang et al. (2012), who stated that reduced tillage in SP provides a more favorable soil physical environment for better crop growth than CT. Pittelkow et al. (2015) and Qi et al. (2011) also reported that higher and more stable crop yields in SP than CT. In CT, heavy smearing of the sub-surface soil by rotary tillage forms a hardpan. Loss of structure, soil degradation and disruption of the soil pores are likely to hamper root growth especially in winter crop.

Moreover, the crop yield increase in SP might have occurred from the improved soil structure and stability. They may facilitate better water holding capacity and drainage that reduces waterlogging and drought extremes (Holland, 2004), ultimately improving soil fertility by sequestering organic carbon in farmland soils (Alam et al., 2019). This finding supports the research result of Liu et al. (2010) who found 20% higher maize yield in SP than CT due to increase of soil organic carbon, soil total nitrogen and soil total phosphorus by 25, 18 and 7%, respectively. These results have implications for understanding how conservation tillage practices increase crop yield by improving soil quality and sustainability in strip tillage practices as also reported by Mvumi et al. (2017). Some research findings also concluded no yield differences between SP and CT. Haque et al. (2017) found the similar grain yield of rice in non-puddled SP transplanting and CT, which confirms the earlier findings of Hossain et al. (2015) who also found no yield penalty of wheat and rice between SP and CT. In another study, Sharma et al. (2011) also reported similar rice yield in SP to the CT. Wiatrak et al. (2005) found identical cotton yield in SP and CT while Al-Kaisi & Licht (2004) found a similar corn and soybean yield in SP and CT. The finding of these studies confirms the result of the present study.

In this study, 50% of previous residues' retention increased the seed yield of crops by about 5% over no-residue. The research finding of Shrivastav et al. (2015) confirm that standing residue converts to mineralized nutrients, which causes sufficient crop growth and facilitates higher yield over no-residue. Qin et al. (2010) concluded straw residue retention directly increases the input of organic matter and nutrients into the soil, improving soil nutrient availability for crop growth and better yield over no-residue. The earlier study of Harrington & Erenstein (2005) also found the benefits of residue retention on crop yield. Improved soil fertility and water availability might occur from the supplies of organic matter from straw residue for heterotrophic N fixing micro-organisms, increasing the nitrogen supply to the crops. Straw residues for controlling weeds in different crops have been suggested by Govaerts et al. (2007), who concluded the crop residues restrict weed growth and thus retards crop-weed competition and a better environment for crops producing the higher yield.

Effect on the benefit-cost ratio

The highest profit from the cultivation of mustard and mungbean was calculated from SP with 50% mulch (Figure 3) followed by the same treatment without mulch, while the CT without mulch fetched the lowest profit. Treatment SP produced a 62% higher profit than CT. Keeping 50% of mulch enhanced benefits by 8.79% relative to no-mulch.

Variation in BCR might be attributed to the variation in major input costs *viz.*, land preparation, labor, and fuel requirements for mustard and mungbean farming under CT and SP systems. Here, tillage operation under CT required (US$ 190.80 ha^{-1}) 5.42% higher than SP (US$ 35.80 ha^{-1}). Hence, about 68% savings occurred in SP relative to CT, which was associated with 33% savings of fuel consumption in SP (5.84 L ha^{-1}) than CT (17.71 L ha^{-1}). The better profit in SP might also be associated with the 29% savings in the labor requirement in SP (106 working days ha^{-1}) than CT (149 working days ha^{-1}) (Figure 3). The seeding ha^{-1} in SP was 12.3 hours quicker than CT taking 18.7 and 6.4 hours in SP and CT, respectively. Labor and time savage in SP was genuinely associated with the simultaneous operation of tillage, seeding, and fertigation (urea and DAP only).

This type of savings in our study agrees with the findings of Haque & Bell (2019). Authors recorded US$ 88.24 - 110.29 costing for one ha of CT but US$ 32.54 - 33.25 for SP. That ultimately saves 70% of the cost for land preparation under SP than CT. Moreover, 49% of savings were achieved from SP over CT's land preparation associated with the 30% savings in fuel and labor requirement was estimated by Islam et al. (2015). This result agrees with the findings of Brouder & Gomez-Macpherson (2014) and Nhamo & Lungu (2017).

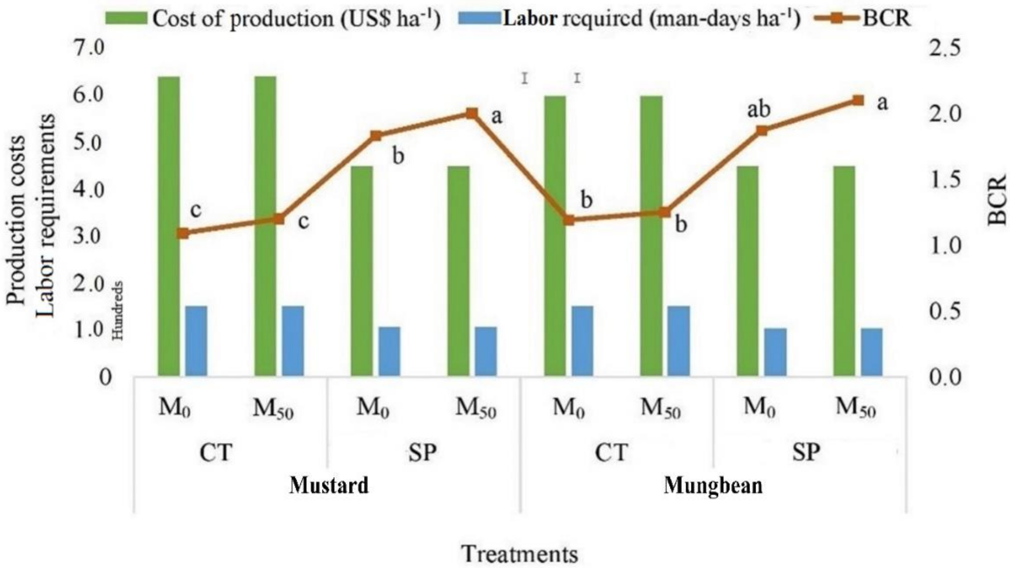

Figure 3. Effect of treatments on production costs, labor requirements and BCR of mustard and mungbean. Means with the similar letter did not vary significantly at $p \leq 0.05$

Conclusion

Strip planting is a novel approach to crop establishment for mustard and mungbean in Bangladesh. Result reveals that strip-planted mustard and mungbean plus 50% of previous crop's residues was a more profitable alternative to the conventionally tilled broadcasting cultivation without retaining any residue. Hence, it could be concluded that the adoption of strip planting plus the retention of increased residue could benefit farmers by incorporating mustard and mungbean in rice-rice and rice-wheat cropping patterns, respectively. There is a vast scope of further research for weed controlling approach in strip planting under different agro-ecological zones of the country for several years to validate this result.

Author declaration

Authors declare that there is no conflict of interest. MMH conducted field experiments, recorded and analysed field data, and prepared the manuscript. MB and MMR supervised the experiment and conducted manuscript proofreading before submission. All authors read and approved the final version of the manuscript.

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