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OPTIMIZING THE SEED RATE FOR MAXIMIZED YIELD AND BENEFITS OF WHEAT UNDER STRIP TILLAGE IN BANGLADESH

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ABSTRACT

An on-farm experiment was conducted at the farmer's field located at the Durbachara village of Gauriopur upazilla under the Mymensingh district of Bangladesh from November 2015 to March 2016 to study the effect of seed rate on yield performance of wheat under strip tillage. Wheat cv. BARI Gom-26 was sown under conventional tillage (CT) vs. strip tillage (ST), including four seeding rates *viz.* 100, 110, 120, and 130 kg ha^{-1}. The CT was done with a two-wheel tractor and consisted of two primary tillages followed by two secondary tillages. The ST was done using a Versatile Multi-crop Planter (VMP) machine in a single pass process. A pre-plant herbicide, glyphosate was applied 3 days before of ST operation @ 3.7 L ha^{-1}. The experiment was laid out in a randomized complete block design with four replications. The impact of tillage methods on the seed rate was found significant in the yield and economic profit of wheat. The longest spike with the highest number of grains $spike^{-1}$, the highest weight of 1000-grain, grain yield, and BCR was recorded when 120 kg seeds of wheat sown with strip tillage. This practice produced a 25% higher yield and earned 51% higher profit than the practice of seeding 100 kg seeds ha^{-1} with conventional tillage.

Keywords: benefit-cost ratio, conventional tillage seed rate, strip-tillage, yield.

INTRODUCTION

Tillage is the mechanical manipulation of soil and plant debris that facilitates crop planting. Tillage kills weeds, controls soil water and air circulation, and mobilizes nutrients for crop growth (Reicosky and Allmaras, 2003). Traditional agriculture, which is heavily mechanized and dependent on conventional tillage (CT), has been

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accused of causing soil degradation, surface and underground water runoff, and increased water use (Brown et al., 2019). The highly mechanized CT has long resulted in exposed field surface, and increasingly worse ecological environment through greenhouse gas emission and valuable time and labor consuming (Hobbs et al., 2008). On the other hand, strip-tillage (ST) has the potential to delay the degradation of plant residues and reduce the release of mineralized inorganic sources of plant nutrients into the soil through preserving optimum soil moisture content (Kassam et al., 2009). During this era of global crisis, it is high time avoiding power tiller-based CT, and minimum tillage based on reduced soil disturbance under strip-tillage can be a new method for maximizing crop yields in global agriculture, with economic and environmental benefits.

Wheat (*Triticum aestivum* L.) is the second most important staple food crop in Bangladesh after rice that grown during the dry, cool season in the month of November to March. Its importance as a crop for food and nutrition security has increased since the independence of the country. Wheat cultivation is comparatively easier and cheaper in terms cultivation costs involving irrigation water, time, and labor than other alternative crops like *Boro* (winter) rice, legumes, and potatoes.

But our country is facing an acute shortage of wheat due to a relatively lower yield of 3.08 t ha^{-1} in less acreage of 4.29 lac hectares as of for the 2014-15 year (BBS, 2016). Among the factors responsible for lower yield and production of wheat in the country, using a higher or lower seed rate is the prime (Ozturk et al., 2006). The higher the seeds, the higher the yield is a common perception among farmers. Sometimes they use a lower seed rate due to the unavailability of seed. Seed rate plays a vital role in optimum plant densities, which is a prerequisite for increasing grain yield through influencing the yield contributing characters (Mahmud et al., 2016). If optimal seeding rates exceed, yield reductions occurred by declining spike number and weight (Laghari et al., 2011), ultimately reducing biological yield (Hasan and Songul, 2010). The higher seed rate above the optimum only enhances production cost without any increase in grain yield (Rafique et al., 2010).

Generally, wheat is cultivated by broadcasting or line sowing method in heavily pulverized conventional tillage (CT) done by a two-wheel tractor or four-wheel power tiller. The bottlenecks and drudgeries of CT could be replaced by adopting ST. This technique offers the potential to reduce soil erosion through a narrow strip of about six inches wide and four to eight inches deep is made in a single pass. This operation helps to conserve soil moisture and consequently ensures soil temperature (Mark and Al-Kaisi, 2005) that are required for the optimum seed germination of wheat. Seeding of wheat in a strip by a machine named Versatile Multi-crop Planter (VMP) machine reduces the use of fuel and production cost by reducing the number of fields passes and additionally, fertilizer can be applied at the same time of seeding with the same machine (Haque et al., 2017). The ST technology can also be used by Bangladeshi farmers to make crops more viable than traditional tillage (Bell et al., 2019). Thus, the on-farm study examined the efficiency of the wheat in the strip tillage method and determined the optimum seed rate to achieve maximum yield.

MATERIALS AND METHODS

Experimental site

An on-farm crop sequence (monsoon rice-wheat-mungbean) 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 (Figure 1).

Figure 1. Map of Bangladesh showing the site of experiment

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 (BARC, 2018). 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 study period, March was the warmest month when the highest maximum temperatures were 30.6 and 31.06℃, and the highest minimum temperatures were 18.4 and 20.2℃ in the first and second year, respectively, followed by February. Temperature declined gradually from November to January. January was the coldest month. November in 2014 and December and March in both years were the driest months when no rainfall was recorded. The highest rainfall event comprising about 20 mm was recorded in February during both years. November and March enjoyed the highest sunshine hours, while December had the least sunshine hours during both years (Figure 2).

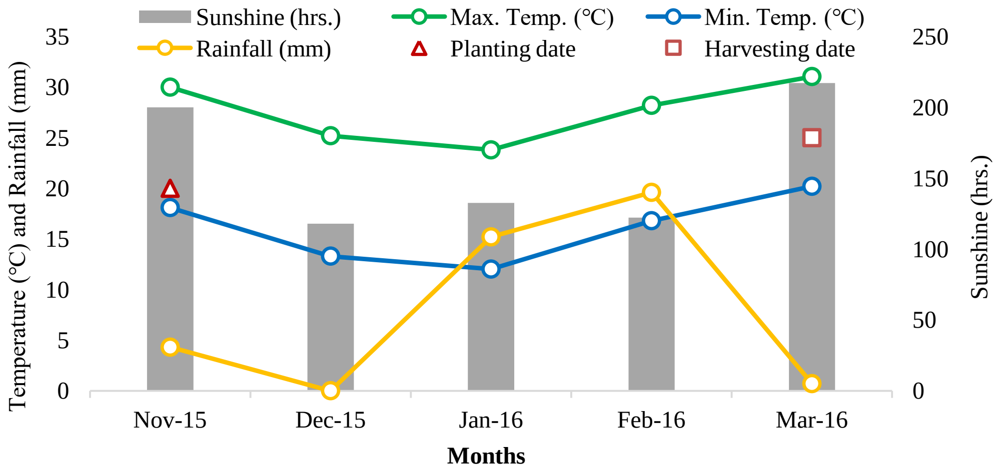

Figure 2. Monthly temperature and rainfall distribution pattern during 2015-16 at Gouripur, Mymensingh, Bangladesh.

Experimental treatments and design

The experiment included four seed rates *viz.* 100, 110, 120, and 130 kg ha^{-1} of BARI Gom-26 and two tillage methods *viz.* conventional tillage (CT) and minimum tillage in the form of strip-tillage (ST). The experiment was laid out in a randomized complete block design with four replications.

Tillage operations

CT was done using a two-wheel tractor (2WT). The land was prepared by four plowing and cross ploughings followed by sun-drying for two days and levels. The SP was done by a Versatile Multi-crop Planter (VMP) in a single pass operation. Strips were prepared for four rows, each 6 cm wide and 5 cm deep. Three days before of ST, glyphosate herbicide was applied @ 3.7 L ha^{-1} (Haque et al., 2017).

Seeding

In CT, seeds were broadcasted manually. In ST, continuous line sowing at 20 cm apart was done using the VMP according to the seed rates. Seeds were covered with soil just after sowing.

Cultural operations

The nitrogen in the form of urea, phosphorus from triple superphosphate, potassium from muriate of potash, and sulfur from gypsum was applied @ 100, 26, 33, and 20 kg ha^{-1}, respectively. The entire amount of PKS was broadcast before seeding. Two-thirds of the N was applied at final plowing and one-third at the crown root initiation (CRI) stage. Weeding was done by hands at 15, 30 and 45 DAS. Irrigations were applied at 20, 55, and 80 DAS. First and third, irrigation was very light, and excess water was drained out to prevent wilt and lodging. Cutworm was controlled by Tricosale® 20EC @ 500 ml ha^{-1}. *Bipolaris* leaf blight was controlled by Tilt® 250EC @ 0.5 ml L^{-1} of water. The bird was kept away for 10 DAS, and rodents were controlled using zinc phosphide poison.

Measurements

The crop was harvested at maturity (when 80% of spikelets turned brown) on March 25, from three randomly selected patches of 3 m × 1 m in each plot. Plant population and number of tillers and spikes m^{-2}, spike length, and the number of spikelets and grains $spikes^{-1}$ were recorded from ten randomly selected hills before harvest. The weight of 1000-grains and grain yield was recorded. Grain yield was adjusted at 14% moisture content, and percent yield increase over control (YOC) was calculated as described below.

$$\mathrm{YOC}(\%) = \frac{\text{yield in treatment} - \text{yield in control}}{\text{yield in control}} \times 100$$

The economics of crop production was estimated following the partial budgeting system. The variable costs were calculated based on labor requirements for sowing/transplanting, weeding, harvesting and threshing, irrigation, fertilization, and all other input costs like seed, fertilizer, irrigation, etc. The gross return was calculated based on the yield and market price of grain and byproducts. The gross benefit was calculated by deducting the variable cost from the gross return. The benefit-cost ratio (BCR) was calculated by using the formula as follows.

$$\mathrm{BCR} = \frac{\text{Gross return}}{\text{The total cost of production}}$$

Statistical analysis

Data were subjected to two-way analysis of variance where Duncans' Multiple Range Test compared means at $P \leq 0.05$. The statistical package program *STAR* (IRRI, 2014) was used to analyze all data.

RESULTS AND DISCUSSION

The interaction effect of tillage practices under different seed rate exerted a significant effect on all the plant characters (Table 1 and Table 2), except plant height, number spikelet $spike^{-1}$ and straw yield (data not shown). We did not find the significant effect of tillage and seed rate individual on wheat (data not shown).

Plant population m^{-2}

Data reveal that the highest plant population m^{-2} area was recorded from ST seeded 130 kg seed ha^{-1} followed by ST with 120 kg seed, CT with 130 and 120 kg ha^{-1} seed, and ST with 110 kg seed ha^{-1} (Table 1). The lowest number of plants m^{-2} was obtained from CT with 100 kg seed $ha^{-1,}$ which was statistically identical to ST with 100 kg ha^{-1} seed. The ST with 130 kg seed produced 51% higher plants than CT with

100 kg seeds. Under the examined seed rates, the ST produced about 8% higher plants than the CT. Overall, under both the tillage types, the 130 kg seed rate generated 39, 21 and 6% higher plants than that of 100, 110 and 120 kg seeds ha^{-1}, respectively (Table 1).

Table 1. Interaction effect of seed rate and tillage practices on yield contributing characters of wheat

Tillage practices	Seed rate (kg ha^{-1})	Plants m^{-2} (no.)	Total tiller m^{-2} (no.)	Spikes m^{-2} (no.)	Spike length (cm)	Grains spike^{-1} (no.)
Conventional tillage	100	89^{d}	267^{g}	210^{cd}	12.18^{c}	50^{b}
	110	102^{cd}	306^{e}	222^{c}	12.06^{cd}	50^{b}
	120	118^{bc}	354^{c}	224^{c}	13.02^{ab}	52^{a}
	130	123^{b}	369^{b}	259^{ab}	11.40^{d}	47^{d}
Strip tillage	100	94^{d}	282^{f}	213^{cd}	12.34^{b}	51^{ab}
	110	111^{c}	333^{d}	239^{bc}	12.25^{b}	50^{b}
	120	125^{b}	375^{b}	271^{a}	13.23^{a}	54^{a}
	130	134^{a}	402^{a}	249^{b}	11.83^{d}	48^{bc}
LSD $_{(0.05)}$		7.03	11.58	13.04	0.21	2.44
CV (%)		4.17	3.06	4.09	4.21	3.09

CV= Co-efficient of variance, LSD= Least Significant Difference, CV= Co-efficient of Variance. In a column, figures with the same letter or without letter do not differ significantly at $p \leq 0.05$.

Number of tillers m^{-2}

The response of plant population to the tillage practice and seed rate have influenced the variation in the number of tillers, respectively (Table 1). The highest number of tillers was recorded in ST seeded 130 kg seeds and lowest from the CT seeded 100 kg seeds followed by plated 120 and 110 kg seeds under ST and CT, respectively. Overall, the ST with 100, 110, 120 and 130 kg seeds produced about 8% higher number of tillers than CT with these seeding rates, respectively. The 130 kg seeds seeded under ST produced 50% higher number of tillers relative to 100 kg seeds under CT.

Number of spikes m^{-2}

The highest number of spikes m^{-2} was recorded from ST with 120 kg seed ha^{-1}, which was statistically similar to CT with 130 seed kg ha^{-1} (Table 1). The second-highest number of spikes m^{-2} was recorded from ST with 130 kg seed ha^{-1} followed by ST with 110 kg ha^{-1} seed. The lowest number of spikes m^{-2} was recorded from CT and ST with 100 kg seed ha$^{-1,}$ which was statistically identical to CT with 120 and 110 kg seed ha^{-1}. About 30% higher number of spikes m^{-2} was found in ST with 120 kg seeds than CT with 100 kg seeds. Overall, ST produced 7% higher number of spikes m^{-2} than that of CT.

The spike length, number of grains spike^{-1} and weight of 1000-grains

The longest spike was found from ST and CT both with 120 kg seed ha^{-1}, which was statistically identical to CT with 120 kg seed ha^{-1} (Table 1). The shortest spike was obtained from CT with 130 kg seed ha$^{-1,}$ which was also statistically like ST with 130 kg seed ha^{-1}. The other treatment combination showed the intermediate result. Similarly, the highest number of grains spike^{-1} (Table 1) and 1000-grain weight (Table 2) was obtained from ST with 120 kg seed ha^{-1} and it was statistically like CT with 120 kg seed ha^{-1} while the lowest value was obtained from ST with 130 kg seed ha^{-1} rate. Overall, the ST with 120 kg seeds produced about the 7% higher values for the spike length, number of grains spike $^{-1}$ and weight of 1000 grains relative to CT with 100 kg seeds ha^{-1}.

Table 2. Interaction effect of seed rate and tillage practices on yield contributing characters and yield of wheat

Tillage Practice	Seed rate (kg ha^{-1})	1000 grain weight (g)	Grain yield		BCR	
			Amount (t ha^{-1})	IOC (%)	Amount	IOC (%)
Conventional tillage	100	53.36^{ab}	3.28^{e}	-	1.87^{e}	-
	110	54.56^{ab}	3.73^{c}	12.06	2.12^{d}	11.79
	120	55.34^{a}	4.21^{ab}	22.09	2.47^{cd}	24.25
	130	52.28^{bc}	3.76^{c}	12.76	2.26^{d}	17.25
Strip tillage	100	53.42^{ab}	3.40^{d}	13.52	2.71^{c}	30.99
	110	53.79^{ab}	3.89^{b}	15.68	2.95^{c}	36.61
	120	55.54^{a}	4.39^{a}	25.28	3.82^{a}	50.65
	130	52.72^{b}	3.87^{b}	15.24	3.3^{b}	37.24
LSD $_{(0.05)}$		1.21	0.18		0.44	
CV (%)		8.69	4.38		3.51	

CV= Co-efficient of variance, LSD= Least Significant Difference, CV= Co-efficient of Variance, BCR= Benefit-Cost Ratio, IOC= Increase Over Control. In a column, figures with the same letter or without letter do not differ significantly at P< 0.05.

Grain yield

The highest grain yield was obtained from ST with 120 kg seed ha^{-1} which was statistically identical to CT with 120 kg seed ha^{-1} and the lowest grain was yielded from CT with 100 kg seed ha^{-1} (Table 2). The 120 kg seeds ha^{-1} either under CT or ST performed the best over other seeding rate but 120 kg seeds under ST produced the highest about 25% higher grain yield over 100 kg seeds under CT. In general, the ST produced 5% higher grain yield relative to CT.

Benefit cost ratio (BCR)

The highest BCR was observed from ST with 120 kg seed ha^{-1} followed by ST with 130 and 110 kg seed ha^{-1} and lowest BCR was calculated from CT with 100 kg seed ha^{-1} (Table 2). Compared to the CT with 100 kg seeds, 120 kg seed generated 24% higher BCR under CT but 51% higher BCR under ST. Overall, ST earned 43% higher BCR than that of CT.

In the present study, the 120 kg ha^{-1} seed rate produced the highest yield followed by 130, and 100 kg and the lowest was recorded from the 100 kg seed ha^{-1}. Yield variation due to the variation of seed rate attributed to the production of the highest number of grains (Naseh et al., 2020) in each of the longest spike (Chhokar et al., 2017) and the accumulation of more dry matter content in the grains (Kumar et al., 2018). The optimum spaced plants grown from 120 kg seeds ha^{-1} had less intra-plant competition, which might contribute to obtaining the bolder seeds in the longest spikes of a higher number m^{-2} area in this present study. This result agrees with the finding of Akhter et al. (2017), stating 120 kg seeds is the optimum for wheat cultivation for getting the highest yield attributed to the best performances of yield contributing characters. Seeding of 120 kg seeds is the best to produce spikelets and grains $spike^{-1}$ that decreased with lower and higher seed rates (Sarker et al., 2007). The highest number of spikelets and grains $spike^{-1}$ is associated with the optimum plant population, and the 1000 seed weight led to obtaining the highest grain yield of wheat in this study.

The present study confirms that the ST is a better alternative to CT in producing a 5% better wheat yield than CT that might have influenced by the beneficial effect of reduced tillage of ST over CT. Any forms of reduced tillage add up to 20% to crop yield and has an effect on the sustainable use of soil resources via its impact on soil characteristics (Khurshid et al., 2006). It also overcome edaphic constraints, whereas inopportune tillage can result in a variety of undesirable consequences, including soil structure destruction, accelerated erosion, loss of organic matter (OM) and fertility, and disruption of water, organic carbon, and plant nutrient cycles (Lal and Stewart, 2013). The ST has a beneficial effect on many elements of the soil, while excessive and CT activities have the reverse effect and are detrimental to the soil and ultimately the yield of crops (Alam et al., 2014). By altering the bulk density and moisture content of the soil, CT techniques alter the soil structure. Furthermore, frequent disturbances caused by CT result in the formation of a finer, looser-setting soil structure, while ST keep the soil intact (Rashidi and Keshavarzpour, 2010). This discrepancy leads in a change in the soil OM properties. Again, the number, size, and distribution of pores influence the soil's capacity to retain and distribute air, water, and agricultural chemicals, thus regulating erosion, runoff, and crop yield (Khan et al., 2001). Where CT was used, losses of soil organic carbon (SOC) and degradation of other characteristics were exacerbated (Powlson et al., 2012). On the other side, ST increases soil quality including SOC storage (Plaza et al., 2013). As reported by

Liao et al. (2002) and Xue et al. (2005), ST practices have been shown to increase crop yield considerably might have resulted to obtain a better wheat yield in ST over CT in the present study probably by improving the status of above stated soil chemical and physical properties in ST.

In this study, the highest BCR achieved from 120 kg seeds ha^{-1} might be attributed to the highest grain yield that is associated with the highest number of boldest wheat grains obtained from the highest number of the longest spikes m^{-2} of this present study. The higher market demand and price for wheat might have obtain a higher BCR of wheat grown under 120 kg seeds ha^{-1} (Sarker et al., 2009; Shah et al., 2011).

In the present study, about 51% higher in BCR in ST than CT can be attributed to the variation in grain yield and main input costs, namely land ploughing, weeding, and labor requirements for wheat cultivation in ST and CT. In this study, land preparation cost US$ 35.3 ha^{-1} in ST but 65.0 ha^{-1} in CT. Hence, ST saved about 45% of land preparation costs than CT. This finding is in the line with Hossain et al. (2020) who observed around 67% savings on land preparation costs in ST (US$ 35.8 ha^{-1}) than CT (US$ 190.8 ha^{-1}) owing to single plowing and lesser amount of diesel/ gasoline usage relative to CT. Another previous research Haque and Bell (2019) claimed a 70% cost savings for plowing in ST as compared to CT, where ST incurred cost of US$ 32.54-33.25 ha^{-1} against US$ 88.24-110.29 ha^{-1} in CT. Again, Islam et al. (2015) reported a 49% of savings were calculated when ST was used instead of CT for land ploughing. Reduction of ploughing costs and increases in grain yield might have achieved a higher BCR in ST over CT in this study.

CONCLUSION

Strip-tillage is a noble practice for wheat cultivation using 120 kg seeds ha^{-1} to achieve the maximum profit. This practice could be the best alternative to conventional tillage using the higher or lower rate than 120 kg of seeds for wheat farming in Bangladesh. To validate this result country wide evaluation of strip-tillage is recommended.

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