

OPTIMUM WATER USE IN CONSERVATION TILLAGE FOR WHEAT CULTIVATION

K. K. SARKER¹, P. K. SARKAR², A. Z. SARKER²
A. M. F. T. ISLAM² AND WANG XIAOYAN¹

Abstract

Conservation tillage system offers numerous benefits over intensive tillage system. This experiment was conducted on conservation tillage using zero till-drill, power tiller operated seeder (PTOS) and bed planter along with farmer's practice of tillage by rotary tiller under different irrigation levels at Wheat Research Centre (WRC), Nashipur, Dinajpur. Irrigation water was applied by 5 irrigation levels at different growth stages of the crop. The irrigation levels were I₀ (No irrigation), I₁ (17-21 DAS), I₂ (17-21 DAS + 50-55 DAS), I₃ (17-21 DAS + 50-55 DAS + 75-80 DAS), and I₄ (17-21 DAS + 35-40 DAS + 50-55 DAS + 75 – 80 DAS). It was observed that the sowing cost was reasonably reduced than that of the farmer's practice. Seasonal water use was less in PTOS than other tillage methods. Grain yield was significantly affected by tillage methods. The higher grain yield was found from PTOS, bed planting, and zero tillage than that of farmer's practice. There was no significant difference within the interaction effect of tillage methods and irrigations. The effect of irrigation level was found highly significant on grain yield. Water use efficiency increased with decrease of irrigation water use and decreased with increase of irrigation. Average yields in all tillage methods under I₁, I₂, I₃, and I₄ irrigation levels were found to increase by 33, 43, 52, and 51 percent, respectively, compared to that of I₀.

Keywords: Conservation tillage, zero till-drill, PTOS, bed planting, and irrigation water.

Introduction

Cultivation and tillage play an important role in agriculture. Traditional soil cultivation system in the tropics and subtropics, with intensive soil tillage, will end in soil degradation and loss of crop productivity. This will result in poverty, exodus of farmers from rural areas, resulting in an increase of city slums and marginal population, and finally in social conflicts (<http://www.Soils.wisc.edu/stro>). Conservation tillage is a set of practices that leave crop residues on the surface to increase water infiltration and reduce erosion. These practices are used in conventional agriculture to reduce the effects of tillage on soil erosion. It uses some of the principles of conservation agriculture (CA) but has more soil disturbance (<http://www.fao.org/ag/ca/1a-html>). Conservation agriculture aims to achieve sustainable and profitable agriculture and subsequently aims at

¹Department of Agricultural Engineering, China Agricultural University, P. O. Box No. 46, Beijing 100083, P. R. China, ²Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701, Bangladesh.

improving livelihoods of farmers. Conservation agriculture manipulates the soil to obtain optimum growth conditions for a crop under increased soil fertility from soil and water conservation. Conservation tillage with management strategies and proper selection can protect the water movement. Tillage of the field before sowing increase initial stands and their survival. Excessive tillage results in late planting and reduces yields of wheat. Tillage operations vary according to water availability, soil texture, topography and farmer's preference for a particular type of culture (De Datta, 1981). Tillage practices that provide conditions for rapid water intake and for temporary storage of water on the soil surface or in the tilled layer help prevent water run-off (Sarker, 1987). Farmers are adopting the new resource conservation technologies (RCTs). At present, it is very important due to shortage of labours and has to be proven in agro-ecological zone of Bangladesh for profitable agricultural production with environmental concerns and sustainability. Justice *et al.* (2004) reported that Chinese Power Tiller Operated Seeder (PTOS) was modified for strip tillage. This was also used to plant *rabi* crops into *aman* rice residue during October/November. One pass tillage (full tillage) was compared to strip tillage. In the strip tillage treatment, half of the tiller blades were removed and the seeds were placed into the tilled strips. Field capacity of the seed drill increased by 25 percent, fuel consumption was reduced by 20 percent and planting cost was reduced by 8 percent compared to those of full tillage treatment. Zero tillage is possible just after rice harvest and present of residual available soil moisture whereas wheat planting is delayed after rice harvest in case of farmers have to pre-irrigate their fields before planting. Zero tillage save this irrigation. Saving in water also comes from the fact that irrigation water advances quicker in untilled soil compared to tilled soil. Aslam *et al.* (1993) showed that zero tillage establishment of wheat after rice gave yields that were equal or even better than that when planted after normal tillage. It was mainly explained by timely planting in the zero-till plots. Bed planting practice is grown in many parts of the world to reduce the cost of production and irrigation water (Abdelhadi *et al.*, 2006). Wheat is a strategic crop and is produced exclusively under irrigation during the short winter season between November and March. Wheat is the second most important staple food in Bangladesh after rice and its production per unit area has increased from 1.95 to 2.13 t/ha in 2008 (WRC, 2008). Productivity per unit area has to be improved due to increasing population growth under limited cultivated land. The optimum use of irrigation water should be an important strategy for increasing agricultural production in Bangladesh. Generally, wheat is sown in November and harvested in March (90 – 115 Days). Loam soils are preferable for good yield of wheat. Seasonally about 250 – 350 mm water is required for wheat production with 1.5 – 4.0 mm as daily evapo-transpiration (Sattar, 2004). Water is the most important factor and critical input for successful crop production. Water should be utilized for optimum and economic yield. Modern high yielding

crop practice methods can be sustained only with good water control and management at the farm level. Water is also the limiting factor for increased food and fiber production to meet the demand of an ever growing population under increasing competition with other uses of water (Municipal, industrial, environmental, etc.). The optimum population of the planet earth depends to a large extent on the availability of water for both raised and irrigated agriculture to grow crops and produce food in the most efficient way (Ali, 2009). Therefore, this research has been undertaken the emphasis on soil conservation and water requirement, improving water use efficiency and relative profitability of conservation agriculture through appropriate crop, fertilizer use and efficient utilization of water and other inputs for wheat cultivation.

The specific objectives were to:

- (i) compare the sowing cost for different tillage methods;
- (ii) determine the seasonal water use in different tillage;
- (iii) determine the effects of tillage and irrigation water on crop yield.

Materials and Method

Physical environment of the study area

The study was conducted during the *rabi* season of 2008-09 at the Wheat Research Centre (WRC), Nashipur, Dinajpur. The site was situated at 25^o45' N latitude and 88^o40' E longitude. The topography of the study area was mainly medium high land and moderately well drained and falls under the old Himalayan Piedmont Plain. The topsoil was non-calcareous brown flood plain (BBS, 2004). The weather of the study area is sub-tropical. During the growing season of wheat, the mean 15 days average weather data were collected from the WRC weather station. Soil samples were collected from 0 – 15, 15 – 30, and 30 – 45 cm depth of the experimental plots randomly to determine soil moisture, bulk density and field capacity by oven dry method. The data on the other major property of soil, such as soil type was collected from the research report of Bodruzzaman and others (2003).

Management of water regimes

The field experiment was laid out in two factors Randomized Complete Block Design (RCBD) using strip plots arrangement and replicated thrice. The unit plot size was 25 m². The research was conducted in zero tillage (ZT), bed planting (BP), power tiller operated seeder (PTOS), and farmer's practice (FP) under different irrigation levels. Irrigation schedule was done in conformation with recommended irrigation practices in the experimental plots (Khair, 1995). Treatment combination comprised 5 levels of irrigation during wheat growth

stages at I_0 (Irrigation no.), I_1 (17-21 DAS), I_2 (17-21 DAS + 50-55 DAS), I_3 (17-21 DAS + 50-55 DAS + 75-80 DAS), and I_4 (17-21 DAS + 35-40 DAS + 50-55 DAS + 75 – 80 DAS). Irrigation scheduling and application rate of each irrigation water for wheat was based on field capacity. Each levee of the plots was compacted manually and used plastic sheet to prevent the seepage and lateral movement. The rainfall (Rf) data was measured using rain gauge. The actual requirement was the depth of water needed to bring the crop rooting zone to field capacity uniformly throughout the field. The net irrigation depth was calculated from the following formula:

$$d = \frac{P_w A_s D}{100}$$

Where, d = Net depth of irrigation water to be applied during irrigation, cm

A_s = Apparent specific gravity

D = Rooting depth to be irrigated, cm

P_w = (FC – RL)

Here,

FC = Field capacity, %

RL = Residual soil moisture level before irrigation, %

The Depth of rooting was considered 45 cm. It is reported that 70 % of total moisture is extracted from the 50 % effective root zone depth (Michael, 1996)

The seasonal crop water use was calculated by the following relationship:

$$SWU = NIR + Rf + \sum_{i=1}^n \frac{(M_{bi} - M_{ei})}{100} \times A_{Si} \times D_i$$

Where, SWU = Seasonal water use, mm

NIR = Total irrigation water depth, mm

Rf = Seasonal rainfall, mm

M_{bi} = Moisture percentage at the beginning of the season in the i^{th} layer of the soil

M_{ei} = Moisture percentage at the end of the season in the i^{th} layer of the soil

n = No. of soil layers in the root zone, D , which was considered of three of layers,

0-15, 15 –30, and 30 – 45 cm.

D_i = Depth of the i^{th} layer of soil within the root zone, mm

A_{si} = Apparent specific gravity of i^{th} layer of soil

Water use efficiency was used in evaluating the yield performance and water management practices. The water utilized by the crop was calculated by the following relationship:

$$\text{Water use efficiency (WUE)} = \frac{\text{Crop yield (kg/m}^2\text{)}}{\text{Seasonal crop water use (m)}} , \text{ kg m}^{-3}$$

Cultural practices

A pre-sowing irrigation was applied for proper seed germination. A high yielding variety BARI Gom-23 (Bijoy) was sown in the experimental plots on 28 November 2008 with the help of zero till- drill (Fig. 1), Bed former (Fig. 2), PTOS (Fig. 3), and farmer's practice (Fig. 4) at the rate of 120 kg/ha. Seeding was done without land preparation by zero till-drill. Bed was formed and seeding was done without prior land preparation. Bed was formed two rows accommodating wheat. Furrow to furrow was 55-56 cm. Bed height was 12 - 13 cm. Irrigation water was applied to the furrows between beds. Ploughing, seeding, and leveling were done through one pass full tillage by PTOS. Tractor operated rotavator was used in farmer's practice for broadcast sowing. Data on sowing cost by tractor operated rotavator were collected from different locations of Dinajpur region. Seeds were treated with Provax-200 @ 3 g/kg of seed. Fertilizers were applied at the rate of $N_{100}+P_{26}+K_{40}+S_{20}+B_1$ kg/ha. Two – thirds of N and total amount of other fertilizers were applied at sowing and the remaining N was top dressed after first irrigation. Weeding was done at 25- 27 DAS by 2-4-D amine @ 1200 ml/ha. At maturity, two samples of each plot in 2 m² for zero till-drill, PTOS, farmer's practices, and 2x 1.1 m for bed planting on 27 March 2009 were harvested. After threshed and cleaned, grain yields were recorded at 12% moisture content. Data on other plant characteristics during harvesting from each of the experimental plot were recorded, such as spike, plant height, spike length, spikelets/spike, grains/spike, thousand grain wt (TGW), and grain yield were recorded. Data were subjected to analysis of variance to sort out significant difference among treatments. DMRT was used to compare treatment means.



Fig. 1. Zerp till-drill



Fig. 2. Bed planting



Fig. 3. PTOS



Fig. 4. Farmer's practice (FP)



Irrigation water (IR) supply



Without IR



With IR

Results and Discussion

Based on the analyses of weather data, the mean monthly minimum and maximum temperatures, relative humidity, total rainfall, sun-shine, and evaporation were shown in Fig. 5, respectively. It has been observed that temperatures were nearly optimum for wheat production. The sun-shine (hr) was not more. The rainfall was very low (15.2 mm) during wheat season. Pan evaporation was normal.

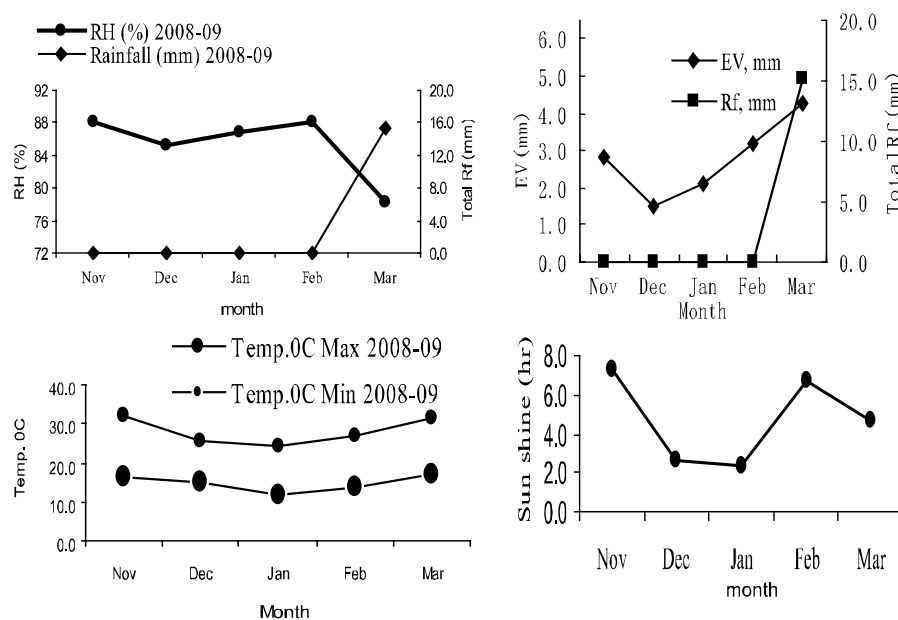


Fig. 5. Mean monthly weather data for the growing season of wheat, 2008-09

The average bulk density, field capacity and soil moisture during sowing were 1.57 g/cc, 24%, and 18%, respectively. The soil type was sandy loam. According to the tillage methods, the sowing cost of wheat in zero tillage, PTOS and bed planting were 58, 56 and 47 % less than that of farmer's practice (Table 1). Similar findings have been reported from the annual research report of Wheat Research Centre (WRC, 2009). The causes of variation of planting cost in different tillages were for different field capacities during operation. Besides this, less time and labour were required than farmer's practice.

Table 1. Cost of sowing by different tillage methods for wheat.

Tillage	Cost of sowing (Tk./ha)	Percent reduction of sowing cost
Farmer's practice (3 passes)	4446	-
Zero tillage (1 pass)	1853	58
Power tiller operated seeder (1 pass)	1976	56
Bed planting (1 pass)	2347	47

Seasonal water requirement was different in different tillage and irrigation options. About 10 percent seasonal water was less required in the tillage system of PTOS than that of farmer's practice under treatment, I₄ (four irrigation) as shown in Table 2 due to conserving more soil moisture, uniformly mixing of soil particles with organic matter and broken capillary tube. Irrigation water was saved during irrigation due to quick advances of streams in untilled soil than tilled soil.

Table 2. Seasonal water use in conservation tillage under different irrigation levels.

Irrigation no.(IR)	Seasonal water use, mm			
	Tillage method			
	ZT	BP	PTOS	FP
I ₀	74	75	73.9	74
I ₁	109	119	104	107
I ₂	159	172	147	147
I ₃	192	202	190	193
I ₄	200	231	195	215

Table 3. The effect of different tillages on grain yield.

Tillage method	Spikes/m ²	G/Spike	Grain yield (kg/ha)
ZT	310.5a	39.4b	3315b
BP	295.9b	41.1a	3393b
PTOS	318.8a	39.9a	3589a
FP	264.2c	38.8b	3214c
F-test	*	*	**
LSD	12.35	1.4	46.86
CV (%)	7.47	5.11	3.83

After data analysis for variance, there was no significant difference on the interaction effect of tillage and irrigation of grain yield. But, the effect of different tillage was found significantly different for grain yield, spikes/m², and grains/spike (Table 3). The results indicated that more grain yield was observed in PTOS than that of farmer's practice due to uniform ploughing, seeding, leveling, proper seed placement, and good germination. Less grain yield was observed in farmer's practice due to less spikes/m² and grains/spike (Table 3) and improper placement of seed during sowing and also less seed germination. On average, 13, 6, and 7% higher grain yields were found from PTOS, zero till-drill and bed planting, respectively, than that of farmer's practice.

Table 4. Percentage of grain yield (GY) increases in FP under different irrigations.

Irrigation treatments	Grain yield (GY), kg/ha								Average % of grain yield
	ZT		BP		PTOS		FP		
	GY	% of GY increases	GY	% of GY increases	GY	% of GY increases	GY	% of GY increases	
I ₀	2472	-	2351	-	2680	-	2401	-	-
I ₁	3150	27	3294	40	3539	32	3202	32	33
I ₂	3431	39	3611	54	3783	41	3377	39	43
I ₃	3736	51	3769	60	3991	49	3530	45	52
I ₄	3784	53	3748	59	3953	48	3560	46	51

Table 5. The effect of irrigation level on grain yield.

IR	Spikes/m ²	Spikelets/m ²	Grains/spike	TGW (g)	Grain yield (kg/ha)	WUE (kg/m ³)
I ₀	265.7d	15.6c	36.7d	55.2b	2476d	3.3a
I ₁	291c	16.7b	37.5c	56.2b	3296c	3b
I ₂	303.2bc	17.7a	41.8a	57.8a	3550b	2.3c
I₃	308.2ab	17.7a	41.8a	58.8a	3756a	1.95d
I ₄	318.7a	17.3a	41b	58.2a	3762a	1.8d
F-test	*	*	**	*	**	**
CV (%)	7.47	2.56	5.11	1.32	3.83	5.92
LSD	14.65	0.53	0.67	1.11	122.2	0.059

The effect of irrigation level was found highly significant on grain yield and the other yield contributing characters (Table 5). It was observed that grain yield in different tillage operations were increased with increased number of irrigation levels. Maximum grain yield was obtained from I₃ level (Three number of irrigations). There was no significant difference on maximum grain yield at I₃ and

I₄ level of irrigation. On average, 33, 43, 52, and 51% yields were increased than that of farmer's practice under I₁, I₂, I₃, and I₄ irrigation levels, respectively (Table 4). These results indicated that wheat was quite responsive to increase yield in optimal or near optimal irrigation. Water use efficiency (WUE) was found significant (Table 5). The results indicated that water use efficiency was found to differ, increase due to less seasonal water use and decrease with increased irrigation. The figures (* and **) within the column indicate 5 % and 1 % level of significance.

Conclusions

From one year study, the experiment supports the following conclusions:

- (i) The sowing cost of wheat could be reduced up to 47, 56, and 58 % by bed planting, PTOS, and zero tillage than conventional practice, respectively.
- (ii) There was no significant difference within the interaction effect of tillage methods and irrigations. About 10 percent seasonal water use was less in PTOS than farmers' practice under four irrigations.
- (iii) The grain yield in that situation was higher from PTOS, bed planting and zero tillage than farmer's practice. On average, 13, 6, and 7% grain yields were found higher from PTOS, zero tillage and bed planting than farmer's practice, respectively.
- (iv) The effect of irrigation level was found highly significant. Average 33, 43, 52, and 51% yields were increased under I₁, I₂, I₃, and I₄ irrigation levels, respectively.
- (v) Optimum water use of zero till-drill, bed planting, PTOS, and farmer's practice were 192, 202, 190, and 193 mm, respectively, under I₃ irrigation level.

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