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Nitrogen Use Efficiency of Wheat and Transplant *Aman* Rice under Bed Planting Method in Rice-Wheat Cropping System

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ABSTRACT

An experiment was conducted at the Bangladesh Rice Research Institute (BRRI) experimental farm, Gazipur and at farmer's field in Chuadanga during Rabi *season 2001-02 (November - March) to* Kharif-II *season 2002 (June - November) to determine the effect of different doses of N fertilizer on growth and yield of wheat and transplant* Aman *rice and to compare the N use efficiency in bed planting and conventional method in rice-wheat cropping system. Bed planting with 0, 60, 80, 100 and 120 kg N ha^{-1} and conventional (flat) method with 0 and 100 kg N ha^{-1} were tested. The yields increase of wheat in bed planting with 80, 100 and 120 kg N ha^{-1} over 100 kg N ha^{-1} in conventional method were 10-21, 20-29 and 23-38%, respectively. For transplant* Aman *rice, bed planting with 80, 100 and 120 kg N ha^{-1} and conventional method with 100 kg N ha^{-1} produced statistically identical grain yield. Bed planting increased the grain number panicle^{-1} and reduced sterility of both wheat and transplant* Aman *rice. Nitrogen use efficiency such as partial factor productivity and agronomic efficiency were higher in bed planting than conventional method and it saved about 20% N without losing yield of wheat and transplant* Aman *rice.*

Key words: Nitrogen use efficiency, rice, wheat and bed planting.

INTRODUCTION

Rice and wheat are the most important food crops in South Asia. About 60% of the farming households live on less than 30% of global agricultural lands (Gupta *et al*., 2003) and approximately 240 million people in South Asia consume rice and/or wheat produced in rice-wheat system (Benites, 2001). Moreover, the annual productivity of the rice-wheat system in the Indo-Gangetic Plain (IGP) is small (5-7 t ha^{-1}) compared with currently attainable (8-10 t ha^{-1}) and site potential (12-19 t ha^{-1}) yields (Aggarwal *et al*., 2000). In Bangladesh, rice covers about 10.5 million ha of land producing 26.5 million tons of grain and contributes over 90% of the total food grain production and wheat covers about 0.5 million ha of land producing 0.7 million tons of grain (BBS, 2007). The continuous cultivation of rice and wheat - two crops or more per year - has provided food and livelihoods for hundreds of thousands of rural and urban poor in South Asia. Now a crisis looms as the population is growing at more than 2% (nearly 24 millions additional mouth to feed) each year and agricultural land area dwindles and yield increase are leveling off (Hobbs, 2003). In order to grow more food from marginal and good quality lands, the quality of natural resource base

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must be improved and sustained. Efficiency of natural resources like, seed, fertilizer, water, fuel and labour require to be improved.

Bed planting in rice-wheat cropping system is a new method for improving resource use efficiency and increasing the yield. In this system, land is prepared conventionally and raised bed and furrows are prepared manually or using a raised bed planting machine. Crops are planted in rows on top of the raised beds and irrigation water is applied in the furrows between the beds. This system is often considered for growing high value crops that are more sensitive to temporary waterlogging stress. Wheat on raised bed though introduced in the IGP few years ago, the practice of rice on narrow raised bed introduced very recently (Connor *et al*., 2003b).

The application of high N rates may result in poor N uptake and low N use efficiency due to excessive N losses. Inefficient N use contributes to greater use of energy resources, increased production costs, and possible pollution of water by nitrates. Proper timing of N application and adequate N rates are critical in meeting plant needs and in improving N use efficiency (Limon-Ortega *et al.,* 2000). Latest research activities in India and Pakistan indicates that bed planting of wheat in rice-wheat system reduces N loses and improved fertilizer use efficiency (Gupta *et al*., 2000; Hobbs and Gupta, 2003; Connor *et al*., 2003a) but a little information is available on bed planting of rice and in Bangladesh it is very new. Therefore, the study was undertaken to determine the effect of N dose on the growth and yield of wheat and transplant *Aman* rice under bed planting and to compare N use efficiency of wheat and transplant *Aman rice* in bed planting with conventional methods in rice-wheat cropping system.

MATERIALS AND METHODS

The experiment was conducted at the Bangladesh Rice Research Institute (BRRI) experimental farm, Gazipur during *Rabi* season 2001-02 (November - March) to *Kharif-II* season 2002 (June - November) and simultaneously at farmer's field in Chuadanga. The soil of the experimental plot at Gazipur was clay loam with pH 6.23 and at Chuadanga it was silty loam with pH 7.30. Bed planting with 0 (Bed 0, control), 60 (Bed 60), 80 (Bed 80), 100 (Bed 100), and 120 (Bed 120) kg N ha^{-1} and conventional (flat) method with 0 (Flat 0, control) and 100 (Flat 100, recommended) kg N ha^{-1} were tested for both wheat and transplant *Aman* rice. The experiment was laid out in a randomized complete block design with three replications for both the crops at both the locations. The unit plot size was 28 m^2 (7 m × 4 m) and 70 m^2 (10 m × 7 m) at Gazipur and Chuadanga, respectively.

Crop management for wheat

The wheat variety Kanchan was used in both the locations and the seed rate was 120 kg ha^{-1}. Seeds were treated with Viatvax-200 at the rate of three gram kg^{-1} seed. Seventy-centimeter wide raised beds (40 cm top and 30 cm furrow) were made manually by spade following the conventional land preparation. The height of beds was 15 cm.

Phosphorus, K, S and Zn were applied at the rates of 36, 25, 20 and 4 kg ha^{-1}, respectively. The N rates were according to the treatments mentioned earlier. Two-thirds N and whole P, K, S and Zn fertilizers were applied at the time of final land preparation. The remaining one-third N was topdressed at 19 days after sowing at crown root initiation i.e. at three leaf stage. This was followed by irrigation. For the treatments with bed planting, N was topdressed on the top of beds only. Seeds were sown in rows in both bed and conventional methods. For beds, seeds were sown in two rows bed^{-1}. For conventional method, row-to-row distance was 20 cm. In the row, seeds were sown continuously and covered properly with soil. The dates of sowing were 22 and 17 November in Gazipur and Chuadanga, respectively. Other recommended crop management practices were followed. Wheat was harvested on 17 and 15 March in Gazipur and Chuadanga, respectively. Grain yield and yield components data were collected at maturity.

Crop management for transplant *Aman* rice

Transplant *Aman* rice variety BRRI dhan30 was used in both the locations. The beds prepared for wheat were kept intact for rice in both the locations. Therefore, rice on bed was grown on zero

tillage condition. After harvesting of wheat the lands were remained fallow in *Kharif-I* season in both the sites. Glycel (41% Glyphosate) @ 3.7 L ha^{-1} was applied 15 days before transplanting for killing weeds. The conventional tillage plots were prepared by puddling.

Phosphorus, K, S and Zn were applied at the rates of 20, 35, 10 and 4 kg ha^{-1}, respectively. The N rates were according to the treatments. In the conventional treatment, the whole of P, K, S and Zn were applied at final land preparation and in bed planting treatments, these basal doses were applied on the top of the beds before transplanting. Urea was topdressed in three equal splits at 15, 30 and 50 days after transplanting. Thirty-day old seedlings were transplanted on 16 and 20 July 2002 in Gazipur and Chuadanga, respectively. Two to three seedlings were transplanted in rows in both bed and conventional methods. The spacing was 20 cm × 20 cm. For the beds, seedlings were transplanted in two rows at 20 cm apart on the top of beds keeping 10 cm at each edge. Irrigation water was applied between the furrows of bed one day before transplanting to make the soil soft. Other recommended crop management practices were followed. In Gazipur, rice was harvested on 04-07 November and in Chuadanga it was harvested on 10-15 November. Grain yield, yield components and other growth parameter data were collected at maturity.

Partial factor productivity (PFP) and Agronomic efficiency (AE) were calculated to compare N use efficiency of wheat and rice. The PFP, grain yield per quantity of N applied was calculated as follows:

$$PFP = \frac{Y}{N_r}$$

Where, Y = Grain yield with applied N (kg ha^{-1}) and N_r = Rate of N fertilizer application (kg ha^{-1}). The AE, grain yield increase from applied N, was calculated as follows:

$$AE = \frac{\Delta Y}{N_r}$$

Where, $\Delta Y = Y - Y_0$, ΔY = Increase in grain yield with N fertilizer (kg ha^{-1}), Y = Grain yield with N fertilizer (kg ha^{-1}), Y_0 = Grain yield without N fertilizer (kg ha^{-1}) and N_r = Rate of N fertilizer application (kg ha^{-1}).

RESULTS AND DISCUSSION

Grain yield and yield components of wheat

Effect of different nitrogen treatments on grain yield and yield components of wheat were significant in both the locations. In Gazipur, N application at the rate of 80, 100 and 120 kg ha^{-1} under bed planting system gave similar yield which were significantly higher than rest of the treatments (Table 1). The yield increase in bed planting with 80, 100 and 120 kg N ha^{-1} over 100 kg N ha^{-1} in conventional were 21, 29 and 38%, respectively. The treatments with 100 kg N ha^{-1} in flat and 60 kg N ha^{-1} in bed planting gave statistically identical grain yield. This result indicated that grain yield of wheat could be increased by bed planting method over conventional method using same dose of N (100 kg ha^{-1}) or even by lower dose (80 kg ha^{-1}) and without losing yield, 40 kg N ha^{-1} (40%) could be saved. The highest grain yield was achieved with 120 kg N ha^{-1} in bed planting (3.05 t ha^{-1}). In Chuadanga, the grain yield under different treatments showed similar trend. The grain yield in bed with 80, 100 and 120 kg N ha^{-1} were also similar. Though the conventional method with 100 kg N ha^{-1} application gave significantly lower grain yield than bed planting with 100 and 120 kg N ha^{-1}, that was comparable with 80 kg N ha^{-1} application in bed planting and higher than that of 60 kg N ha^{-1}. This result revealed that wheat yield could be raised by using bed planting method with similar dose of N (100 kg ha^{-1}) and at least 20 kg N ha^{-1} (20%) could be saved over conventional method without yield loss in farmers' field condition, though the N saving was higher in Gazipur site. The yield increase in bed planting with 80, 100 and 120 kg N ha^{-1} over 100 kg N ha^{-1} in conventional were 10, 20 and 23%, respectively. Like Gazipur location, the highest grain yield was recorded with 120 kg N ha^{-1} application in bed planting.

Table 1. Effect of nitrogen rate on the yield and yield components of wheat under bed planting in rice-wheat cropping system at Gazipur and Chuadanga

Nitrogen rate (N kg ha^{-1})	Gazipur				Chuadanga			
	Grain yield (t ha^{-1})	Panicles m^{-2} (no.)	Grains panicle^{-1} (no.)	1000-grain wt. (g)	Grain yield (t ha^{-1})	Panicles m^{-2} (no.)	Grains panicle^{-1} (no.)	1000-grain wt. (g)
Bed 0 (Control)	0.80 c	174 d	14.8 c	36.8 b	0.90 d	178 d	15.3 d	35.9 b
Bed 60	2.17 b	270 b	32.4 a	42.3 a	2.52 c	279 c	32.7 b	41.5 a
Bed 80	2.75 a (21)*	280 b	33.9 a	42.6 a	2.92 ab (10)	292 bc	35.3 a	41.8 a
Bed 100	2.93 a (29)	319 a	34.9 a	42.0 a	3.17 a (20)	329 ab	35.0 ab	42.1 a
Bed 120	3.05 a (38)	327 a	35.7 a	42.7 a	3.25 a (23)	336 a	36.7 a	42.4 a
Flat 0 (Control)	0.78 c	209 c	12.2 c	31.5 c	0.93 d	211 d	12.7 e	32.0 c
Flat 100 (Recommended)	2.28 b	316 a	26.7 b	40.9 a	2.65 bc	327 ab	27.7 c	40.5 a
CV (%)	9.55	5.78	9.60	5.41	7.75	7.29	5.00	4.54

Figures in a column followed by different letters differ significantly at 5% level of probability as per DMRT.
*Figures in the parenthesis are the yield increased (%) over conventional recommended control (100 kg N ha^{-1}).

The highest number of panicles m^{-2} was attained with 120 kg N ha^{-1} application in bed planting, which was statistically identical to that of 100 kg N ha^{-1} application in both bed and flat and significantly higher than other treatments in both the locations (Table 1). In Gazipur site, the number of panicles m^{-2} in bed planting with 60 and 80 kg N ha^{-1} was similar and that were lower than the treatments with 100 kg N ha^{-1} application in both bed and flat. However, in Chuadanga site, in bed with 80 kg N ha^{-1} produced similar number of panicles m^{-2} to 100 kg N ha^{-1}. Even though the 100 kg N ha^{-1} application in flat was capable to produce similar number of panicles m^{-2} to bed planting with 80, 100 and 120 kg N ha^{-1}, the grain yield was lower because of lower number of grains panicle^{-1} and lower 1000-grain weight. The number of grains panicle^{-1} was significantly higher in bed planting with different doses of N fertilizer than conventional method with 100 kg N ha^{-1} in both the locations. The grain weight of wheat also varied with the application of different treatments. Though the bed planting with different doses of N application and flat with 100 kg N ha^{-1} application achieved statistically identical 1000-grain weight, it was lower in flat method.

Grain yield and yield components of transplant *Aman* rice

Grain yield and yield components of transplant *Aman* rice significantly differed with different treatments of nitrogen in bed planting and conventional method in both Gazipur and Chuadanga site. Bed planting with 80, 100 and 120 kg N ha^{-1} and conventional method with 100 kg N ha^{-1} produced statistically identical grain yield in both the locations (Table 2). The lowest grain yield was recorded by the treatments without N fertilizer in bed and flat in both the locations.

The number of panicles m^{-2} of transplant *Aman* rice also varied due to use of different N treatments in bed and flat in both the locations. In Gazipur, application of 80, 100 and 120 kg N ha^{-1} in bed gave higher number of panicles m^{-2} than 100 kg N ha^{-1} in flat. Whereas in Chuadanga, 80, 100 and 120 kg N ha^{-1} in bed and 100 kg N ha^{-1} in flat gave statistically identical number of panicles m^{-2}. The plots without N treatments produced lower number of panicles m^{-2} in both the locations. The difference in number of panicles m^{-2} corresponded to differences in yields of the respective treatments. Bed planting with 80, 100 and 120 kg N ha^{-1} produced statistically identical number of grains panicle^{-1} in both the locations. The highest number of grains panicle^{-1} was recorded in bed with 80 kg N ha^{-1} in Gazipur and with 120 kg N ha^{-1} in Chuadanga, which were significantly higher than that of bed planting with 60 kg N ha^{-1} and conventional with 100 kg N ha^{-1}. The lowest number of grains panicle^{-1} was found in the plots without N fertilizer in both the locations. The 1000-grain weight of transplant *Aman* rice achieved by different treatments did not differ significantly in both the locations.

Table 2. Effect of nitrogen rate on the yield and yield components of transplant *Aman* rice under bed planting in rice-wheat cropping system at Gazipur and Chuadanga

Nitrogen rate (N kg ha^{-1})	Gazipur				Chuadanga			
	Grain yield (t ha^{-1})	Panicles m^{-2} (no.)	Grains panicle^{-1} (no.)	1000-grain wt. (g)	Grain yield (t ha^{-1})	Panicles m^{-2} (no.)	Grains panicle^{-1} (no.)	1000-grain wt. (g)
Bed 0 (Control)	3.19 c	181 c	86 c	21.1	3.01 c	175 c	83 d	23.2
Bed 60	4.82 b	230 a	112 b	21.3	4.96 b	214 b	113 b	23.6
Bed 80	5.22 a	234 a	122 a	21.2	5.30 a	223 ab	116 ab	23.8
Bed 100	5.31 a	236 a	119 ab	21.3	5.42 a	227 a	118 ab	24.1
Bed 120	5.42 a	240 a	118 ab	21.4	5.33 a	224 ab	120 a	23.9
Flat 0 (Control)	3.08 c	205 b	80 c	21.0	2.89 c	184 c	85 d	23.1
Flat 100 (Recommended)	5.18 a	237 a	112 b	21.2	5.21 a	230 a	105 c	23.7
CV (%)	3.48	4.52	4.47	3.47	2.84	2.67	3.03	1.85

Figures in a column followed by different letters differ significantly at 5% level of probability as per DMRT.

Other plant attributes of wheat

Plant height, panicle length, non-bearing tillers, sterility, straw yield and harvest index of wheat were significantly affected by different rates of N fertilizer in both the locations (Table 3). The plant heights with 60, 80, 100 and 120 kg N ha^{-1} in bed were similar, which were significantly higher than that of 100 kg N ha^{-1} in flat and the plots without N fertilizer. In Gazipur, the longest panicle was found in with 120 kg N ha^{-1}, which was statistically identical to those in bed with 60, 80 and 100 kg N ha^{-1} and significantly higher than that of 100 kg N ha^{-1} in flat and the plots without N fertilizer. However, the panicle length of wheat in flat with 100 kg N ha^{-1} was statistically similar to that of bed with 60 and 80 kg N ha^{-1}. In Chuadanga, the panicle length in bed with 120 and 100 kg N ha^{-1} was statistically identical. Similarly, panicle length in bed with 100 kg N ha^{-1} was similar to that of 80 kg N ha^{-1} and it was higher than flat with 100 kg N ha^{-1}. The longer panicles in beds with different N rates obviously helped in getting higher number of grains panicle^{-1} in the corresponding treatments.

Table 3. Effect of nitrogen rate on the growth parameters of wheat under bed planting and conventional method in rice-wheat cropping system at Gazipur and Chuadanga

Nitrogen rate (N kg ha^{-1})	Plant height (cm)	Panicle length (cm)	Non-bearing tillers (no. m^{-2})	Sterility (%)	Straw yield (t ha^{-1})	Harvest index
			Gazipur			
Bed 0 (Control)	78.0 c	7.9 c	7.7 a	21.8 a	2.40 c	0.25 b
Bed 60	95.3 a	13.1 ab	3.3 b	13.3 c	4.40 b	0.33 a
Bed 80	96.0 a	13.4 ab	2.7 b	12.7 c	4.89 ab	0.36 a
Bed 100	96.3 a	13.8 a	2.7 b	12.3 c	5.21 ab	0.36 a
Bed 120	97.4 a	14.2 a	3.0 b	11.8 c	5.66 a	0.35 a
Flat 0 (Control)	76.7 c	7.1 c	9.0 a	23.0 a	2.47 c	0.24 b
Flat 100 (Recommended)	86.3 b	12.0 b	8.3 a	17.3 b	5.07 ab	0.31 a
CV (%)	1.37	6.88	18.71	7.36	4.23	7.85
			Chuadanga			
Bed 0 (Control)	77.2 c	8.1 d	7.3 a	22.5 a	2.56 f	0.26 d
Bed 60	95.4 a	13.1 c	4.3 b	13.7 c	5.12 d	0.33 b
Bed 80	96.5 a	13.5 bc	3.7 b	13.2 c	5.42 c	0.35 a
Bed 100	97.6 a	14.4 ab	3.7 b	12.8 c	5.89 b	0.35 a
Bed 120	98.9 a	14.8 a	3.3 b	12.5 c	6.04 ab	0.35 a
Flat 0 (Control)	79.9 c	7.3 d	8.3 a	23.4 a	2.92 e	0.24 d
Flat 100 (Recommended)	87.4 b	12.6 c	7.7 a	18.9 b	6.18 a	0.30 c
CV (%)	2.67	5.47	19.72	5.60	2.68	6.52

Figures in a column followed by different letters differ significantly at 5% level of probability as per DMRT.

The number of non-bearing tillers was reduced by application of 60, 80, 100 and 120 kg N ha^{-1} in bed as compared to flat with 100 kg N ha^{-1} and without N in both the locations. Similarly, significantly lower sterility (%) was recorded in the bed with 60, 80, 100 and 120 kg N ha^{-1} than flat with 100 kg N ha^{-1} and without N. In Gazipur, statistically identical straw yields were recorded in the treatments in bed with 80, 100 and 120 kg N ha^{-1} and in flat with 100 kg N ha^{-1}. In Chuadanga, the highest straw yield was recorded in flat with 100 kg N ha^{-1} and it was statistically identical to the bed with 120 kg N ha^{-1} which was followed by bed with 100 kg N ha^{-1}. In Gazipur, there were no significant differences in harvest indices of 60, 80, 100 and 120 kg N ha^{-1} in bed and 100 kg N ha^{-1} in flat, though it was generally lower in flat. In Chuadanga, harvest indices of the treatments 80, 100 and 120 kg N ha^{-1} in bed were similar, and significantly higher than that of other treatments.

Other plant attributes of transplant *Aman* rice

Plant height, panicle length, non-bearing tillers, sterility, straw yield and harvest index of transplant *Aman* rice were also significantly affected by different rates of N fertilizer in both the locations (Table 4). The plant heights in bed planting with 80, 100 and 120 kg N ha^{-1} were significantly higher than all other treatments in bed planting and conventional method. Like plant height, the panicle length achieved by the treatments in bed planting with 80, 100 and 120 kg N ha^{-1} were similar and significantly higher than rest of the treatments. The smaller panicles were found in the treatments without N fertilizer in both the locations. The longer panicles in different bed planting treatments might be an advantage of getting higher number of grains $panicle^{-1}$, which positively contributed to the grain yield.

Table 4. Effect of nitrogen rate on the growth parameters of transplant *Aman* rice under bed planting and conventional method in rice-wheat cropping system at Gazipur and Chuadanga

Nitrogen rate (N kg ha^{-1})	Plant height (cm)	Panicle length (cm)	Non-bearing tillers (no. m^{-2})	Sterility (%)	Straw yield (t ha^{-1})	Harvest index
			Gazipur			
Bed 0 (Control)	105.6 e	20.1 c	7.7 a	35.6 a	3.45 f	0.48 ab
Bed 60	115.8 c	26.3 ab	4.0 b	26.7 b	5.02 d	0.49 a
Bed 80	117.3 bc	27.0 a	3.7 b	25.3 b	5.33 c	0.49 a
Bed 100	118.5 ab	27.1 a	2.7 b	24.2 b	5.40 c	0.50 a
Bed 120	120.1 a	27.4 a	3.3 b	26.4 b	5.64 b	0.49 a
Flat 0 (Control)	104.5 e	18.4 c	9.0 a	37.0 a	3.61 e	0.46 c
Flat 100 (Recommended)	112.0 c	24.1 b	7.3 a	30.9 ab	5.84 a	0.47 bc
CV (%)	0.83	6.52	22.82	13.79	1.55	1.99
			Chuadanga			
Bed 0 (Control)	104.5 d	20.3 d	8.7 a	34.9 a	3.39 e	0.47 bc
Bed 60	111.4 c	25.4 b	4.3 b	26.0 c	5.16 d	0.49 ab
Bed 80	115.5 b	26.0 ab	4.0 b	25.5 c	5.35 c	0.50 a
Bed 100	117.2 ab	26.5 a	3.7 b	24.1 c	5.50 b	0.50 a
Bed 120	118.0 a	26.9 a	3.3 b	25.3 c	5.77 a	0.48 b
Flat 0 (Control)	103.7 d	18.3 e	9.7 a	36.3 a	3.45 e	0.46 c
Flat 100 (Recommended)	110.7 c	24.4 c	8.0 a	31.5 b	5.88 a	0.47 bc
CV (%)	1.00	2.05	16.26	4.76	1.32	2.42

Figures in a column followed by different letters differ significantly at 5% level of probability as per DMRT.

Number of non-bearing tillers m^{-2} found in the treatments without N fertilizer in both bed and flat and 100 kg N ha^{-1} in flat were statistically identical and those were higher than the treatments 60, 80, 100 and 120 kg N ha^{-1} in bed. The lower number of non-bearing tillers m^{-2} in beds with different N rates might be responsible for higher number of panicles in corresponding treatments. Likewise, application of 60, 80, 100 and 120 kg N ha^{-1} in bed reduced sterility percentage.

Significantly the highest straw yield was recorded in the treatment with 100 kg N ha^{-1} in flat whereas harvest indices were higher in bed planting with 60, 80, 100 and 120 kg N ha^{-1}.

Nitrogen use efficiency for wheat

The nitrogen use efficiency was compared in terms of partial factor productivity (PFP) and agronomic efficiency (AE). The PFP (kg grain kg^{-1} N) was higher in all bed planting treatments than conventional method with 100 kg N ha^{-1} at both Gazipur and Chuadanga (Table 5). Bed planting with 60 kg N ha^{-1} resulted in the highest PFP (36.17 – 42.00 kg grain kg^{-1} N) and with the increase in N rate, the PFP was decreased in both the locations.

The AE (kg grain increased kg^{-1} N) was also higher in all bed planting treatments than conventional method with 100 kg N ha^{-1}, whether it was calculated either using the control treatment (0 kg N ha^{-1}) in raised bed or flat method at both the locations. At Gazipur, the highest AE was recorded in bed planting with 80 kg N ha^{-1} (24.38 - 24.63 kg grain increased kg^{-1} N), followed by 60 kg N ha^{-1} in bed planting and with the increase of N rate from 80 kg ha^{-1}, the AE was decreased. In Chuadanga, the highest AE was found in bed planting with 60 kg N ha^{-1} (27.00 - 26.50 kg grain increased kg^{-1} N) and with the increase of N rate the AE was decreased. In Gazipur, the grain yield of wheat with 60 kg N ha^{-1} was lower than that of Chuadanga, resulting in lower AE to some extent. The results of two locations indicated the advantage of bed panting over conventional method in N use efficiency. The higher N use efficiency by bed planting compared to conventional method was also reported by Gupta *et al*. (2000), Hobbs and Gupta (2003), Hobbs and Sayre (2003), Conor *et al*. (2003b), Meisner et *al*. (2005), Ram *et al*. (2005) and Sayre et *al*. (2005).

Table 5. Partial factor productivity (PFP) and Agronomic efficiency (AE) of nitrogen use of wheat under bed and conventional planting with different nitrogen rates, Gazipur and Chuadanga

Nitrogen rate (N kg ha^{-1})	PFP (kg grain kg^{-1}N)		AE (kg grain increased kg^{-1}N)			
			Using 0 N in bed		Using 0 N in flat	
	Gazipur	Chuadanga	Gazipur	Chuadanga	Gazipur	Chuadanga
Bed 0 (Control)	-	-	-	-	-	-
Bed 60	36.17	42.00	22.83	27.00	23.17	26.50
Bed 80	34.38	36.50	24.38	25.25	24.63	24.88
Bed 100	29.30	31.70	21.30	22.70	21.50	22.40
Bed 120	25.42	27.08	18.75	19.58	18.92	19.33
Flat 0 (Control)	-	-	-	-	-	-
Flat 100 (Recommended)	22.80	26.50	14.80	17.50	15.00	17.20

Nitrogen use efficiency for transplant *Aman* rice

For transplant *Aman* rice, bed planting with 60, 80, and 100 kg N ha^{-1} resulted in higher PFP than conventional method with 100 kg N ha^{-1} at both the locations. However, bed planting with 120 kg N ha^{-1} recorded the lowest PFP at each location (Table 6). The highest PFP was recorded in bed planting with 60 kg N ha^{-1} (80.33 - 82.67 kg grain kg^{-1} N) and with the increase in N rate, the PFP was decreased at every location.

The AE calculated either using the control treatment (0 kg N ha^{-1}) of raised bed or flat method, followed similar pattern. The AE of conventional method with100 kg N ha^{-1} was considerably lower than bed planting with 60, 80 and 100 kg N ha^{-1} but higher than 120 kg N ha^{-1} at each location. The highest AE was resulted in bed planting with 60 kg N ha^{-1} at both Gazipur (27.17 – 29.00 kg grain increased kg^{-1} N) and Chuadanga (32.50 - 34.50 kg grain increased kg^{-1} N). With the increase in N rate, the AE was decreased at every location. From the results of two locations it was revealed that the bed planting system could use N more efficiently than conventional method.

Table 6. Partial factor productivity (PFP) and Agronomic efficiency (AE) of nitrogen use of transplant *Aman* rice under bed and conventional planting with different nitrogen rates, Gazipur and Chuadanga

Nitrogen rate (N kg ha^{-1})	PFP (kg grain kg^{-1}N)		AE (kg grain increased kg^{-1}N)			
			Using 0 N in bed		Using 0 N in flat	
	Gazipur	Chuadanga	Gazipur	Chuadanga	Gazipur	Chuadanga
Bed 0 (Control)	-	-	-	-	-	-
Bed 60	80.33	82.67	27.17	32.50	29.00	34.50
Bed 80	65.25	66.25	25.38	28.63	26.75	30.13
Bed 100	53.10	54.20	21.20	24.10	22.30	25.30
Bed 120	45.17	44.42	18.58	19.33	19.50	20.33
Flat 0 (Control)	-	-	-	-	-	-
Flat 100 (Recommended)	51.80	52.10	19.90	22.00	21.00	23.20

CONCLUSION

From the results of two locations it could be obviously concluded that 10-38% grain yield of wheat could be increased by bed planting method over conventional method and 20-40% N could be saved without yield loss. For transplant *Aman* rice, 20% N could be saved without losing yield. These savings were attained due to higher N use efficiency of both the crops in bed planting method than conventional method.

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