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Growth of Wheat (*Triticum aestivum* L.) under Raised Bed Planting Method in Rice-Wheat Cropping System

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ABSTRACT

An experiment was conducted at the Bangladesh Rice Research Institute, Gazipur during Rabi season 2001-02 and 2002-03 (November to March) to evaluate the effect of raised bed planting method on different crop growth parameters, which influence the wheat productivity. Total tiller production, leaf area index (LAI), dry mater production (DMP), crop growth rate (CGR) and agronomic productivity of wheat under bed planting on 70, 80 and 90 cm wide beds with two and three plant rows bed^{-1} and conventional method were investigated. The number of tillers m^{-2} in 70 cm beds with both two and three rows were statistically identical to conventional method. Wheat plants grown on narrow beds (70 cm) produced similar LAI to that grown in conventional method but plants in wider beds (80 and 90 cm) had less LAI than that in conventional method. Similarly, DMP and CGR in 70 cm beds were either comparable or higher than conventional method. Grain yield of 70 cm beds were higher than conventional method. Wheat in 70 cm beds increased number of panicles m^{-2}, number of grains panicle^{-1} and 1000-grain weight of wheat.

Key words: Bed planting, rice-wheat and wheat growth

INTRODUCTION

Bed planting in rice-wheat cropping system is an alternative tillage and crop establishment method for improving resource use efficiency and increasing the yield frontier (Hobbs *et al*., 2001). In this system, the 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. Water moves horizontally from the furrows into the beds. This system is often considered for growing high value crops that are more sensitive to temporary water-logging stress. Growing wheat on raised beds though introduced in the Indo-Gangetic Plain few years ago, the practice of rice, the major water-using crop in the rice-wheat cropping system, on narrow raised bed introduced very recently (Connor *et al*., 2003b). In rice-wheat cropping system, new raised beds are prepared for wheat and after harvesting of wheat, rice is grown in Aman season (*Kharif-II*) following a required repairing of the beds. An additional advantage of bed planting becomes apparent when beds are permanent, that is, when they are maintained over the medium term and not broken down and reformed for every crop (Hobbs and Gupta, 2003a, Sayre, 2003). In the permanent bed, all the crops of the system, except the first crop in the first year, grown in zero tillage, which cut down the costs of land preparation and bed making, and only repairing cost for bed is needed.

The continuous cultivation of rice and wheat - two crops or more per year - has provided food and livelihoods for millions 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 levelling off (Hobbs, 2003). Increasing food production of this area in the next 20 years to match population growth is challenging. It is made even more difficult because, land area devoted to agriculture will be stagnated or declined and better quality land and water resources is expected to be diverted to other sector of the national economy. In order to grow more food from marginal and good quality lands, the quality of natural resource base must be improved and sustained. Efficiency of natural resources like, seed, water, fuel and labour needs to be improved and that conservation

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technologies like bed planting technology (Hobbs *et al.*, 2001).

Research activities in India and Pakistan showed many advantages of bed planting in rice-wheat systems. The bed planting in rice-wheat systems saved 50% seed and 30-40% water, increased yield, reduced lodging, facilitated mechanical weeding, offered opportunity for a last irrigation at grain filling stage of wheat, avoided temporary water logging problem, allowed surface basal and top dress fertilizer placement, reduced N loses and promoted rain water conservation (Moreno *et al.*, 1993, Gupta *et al.*, 2000; Connor *et al.*, 2003a). The soil on the surface of the bed is drier, which is not favourable for weed growth (Malik *et al.*, 1998). Lodging problem is also less on raised bed (Meisner *et al.*, 1992). Additional light enters the canopy and strengthens the straw and soil around the base of the plant. Adoption of bed planting has increased dramatically in the last decade in the high yielding irrigated wheat growing area of northwestern Mexico. It has increased from 6% in 1981 to 75% in 1994 due to improved and efficient management of irrigation water; improved fertilizer use efficiency; better weed management; lower seed rate and better plant stands; better drainage and less lodging of wheat (Hobbs and Gupta, 2003a). The research activities on bed planting of wheat so far done and/or reported are mainly on the productivity and resource conservation. Therefore, this study was undertaken to evaluate the effect of bed planting on different crop growth parameters, which influence the agronomic productivity of wheat.

MATERIALS AND METHODS

The study was carried out at the Bangladesh Rice Research Institute (BRRI), Gazipur during Rabi season 2001-02 and 2002-03 (November to March). The soil of the experimental plot was clay loam with pH6.78. Bed planting in 70, 80 and 90 cm (center- to-center of furrows) wide bed with two and three plant rows bed^{-1} along with flat (conventional) planting were tested. The experiment was laid out in a randomized complete block design with four replications. The unit plot size was 24 m^2. Wheat variety Kanchan was used and seed rate was 120 kg^{-1}. Raised beds and furrows were made manually by spade following the conventional land preparation in the first year. According to the treatments 70, 80 and 90 cm wide beds were made. The height of beds was 15 cm. In the second year, no new beds were made. The beds of the previous year where wheat followed by direct seeded Aman rice were grown kept as permanent bed. It was repaired before seeding of next year's wheat.

Nitrogen, P, K, S and Zn were applied at the rates of 100, 36, 25, 20 and 4 kg ha^{-1}, respectively. In the first year, two-thirds N and whole P, K, S and Zn fertilizerswere applied at final land preparation. The remaining one-third N was topdressed at 20 days after sowing (DAS) at crown root initiation (CRI) i.e. three leaf stage. This was followed by irrigation. For the treatments with bed planting, N was applied on the top of beds only. In the second year, the basal doses of fertilizer were applied at final land preparation in the plots with conventional tillage treatment but in the plots with bed planting treatments, the basal doses were applied before sowing on the top of the beds. Seeds were sown in rows in both bed and conventional methods. For beds, seeds were sown in two and three rows according to the treatments. For conventional method, row-to-row distance was 20 cm. In the row, seeds were sown continuously and covered with soil properly. The dates of sowing were 29 and 20 November in the first and second year,respectively. Other recommended crop management practices were followed.

Tiller number, leaf area index (LAI), dry matter production (DMP) and crop growth rate (CGR) were recorded at 10 day intervals starting from 20 DAS. Three sample areas, one square meter each, were marked by bamboo stick in each plot to count total tiller production and panicle number. To measure LAI, from each plot, plant sample of 0.25 m^{-2} were collected from outside the harvest area excluding border plant rows. Whole sample plants were uprooted. Six representative tillers from each sample were removed as sample tillers. Green leaves of sample tillers were removed. The leaf area of sample tillers was measured by using an automatic leaf area meter. Other green leaves from the each sample were removed from the tillers. Then leaves from the sample tillers and leaves from the other tillers of the samples were dried and weighed separately. The LAI was computed by using the method given by Yoshida *et al.* (1976) as follow:

Leaf area of the sample =

$$\frac{\text{Total leaf area of the sample tillers (cm}^2) \times \text{Dry wt of all leaves (g)}}{\text{Dry wt of leaves from sample tillers (g)}}$$

Where, dry wt of all leaves = dry wt of sample leaves + dry wt of remaining leaves

$$\text{LAI} = \frac{\text{Leaf area of the sample (cm}^2)}{\text{Area of land covered by the sample (cm}^2)}$$

Dry matter production and CGR were measured from the same samples collected for LAI. The plant samples were dried in an oven at 80°C until to reach a constant dry weight. Total dry matter was expressed in g m^{-2} and crop growth rate in g day^{-1} m^{-2}. Wheat was harvested on 28 and 21 March in the first and second year, respectively. Grain yield and yield components data were collected at maturity.

RESULTS AND DISCUSSION

Tiller production

In the first year, where wheat was sown on new beds, at beginning (20 DAS), the number of tillers m^{-2} in conventional method was significantly higher than all bed planting treatments and with the progressing of the days from seeding, the differences became reduced and finally no difference was observed between conventional method and bed planting with 70 cm beds (Table 1). At 30 DAS the tiller production in conventional method was comparable to 70 cm beds with three plant rows. However, at 40 DAS it was statistically identical to 70 cm beds with both two and three rows. At 50 DAS the number of tillers m^{-2} was higher in 70 cm beds with both two and three rows than conventional method. From 60 to 120 DAS (maturity) the number of tillers m^{-2} in bed with both two and three rows was statistically similar to conventional method. The number of tillers m^{-2} was decreased with the increase in bed width with the same plant rows per bed, and three rows per bed produced slightly higher number of tillers m^{-2} than two rows per bed in the same bed width.

Table 1. Tiller production of wheat under different planting methods at different days after seeding (DAS)

Planting method	Tillers (no. m^{-2}) at DAS										
	20	30	40	50	60	70	80	90	100	110	120
						2001-02					
70 cm bed + 2 rows	148 cd	243 b	358 a	363 a	347 a	336 a	329 a	319 a	313 a	311 a	309 a
70 cm bed + 3 rows	159 b	246 ab	350 a	354 ab	341 a	338 a	336 a	327 a	321 a	319 a	318 a
80 cm bed + 2 rows	149 cd	224 c	310 b	314 c	286 b	276 b	272 b	251 b	240 c	237 c	235 c
80 cm bed + 3 rows	152 bcd	214 d	285 c	289 d	273 c	266 bc	262 bc	255 b	252 b	249 d	248 b
90 cm bed + 2 rows	144 d	200 e	270 d	273 e	257 d	249 d	244 d	232 c	226 d	224 d	223 d
90 cm bed + 3 rows	155 bc	208 d	275 cd	279 de	263 cd	259 cd	256 c	245 b	240 c	237 c	235 c
Conventional	175 a	252 a	349 a	352 b	339 a	334 a	331 a	324 a	321 a	318 a	315 a
						2002-03					
70 cm bed + 2 rows	154 a	259 b	354 ab	359 ab	346 b	332 b	322 b	317 b	312 b	311 b	310 b
70 cm bed + 3 rows	160 a	279 a	360 a	375 a	362 a	354 a	346 a	339 a	329 a	328 a	325 a
80 cm bed + 2 rows	153 a	239 c	300 de	318 d	297 d	288 d	280 d	272 d	265 d	263 d	260 d
80 cm bed + 3 rows	155 a	245 bc	318 cd	338 c	316 c	308 c	301 c	293 c	286 c	285 c	282 c
90 cm bed + 2 rows	153 a	207 d	287 e	296 e	268 f	252 e	253 e	248 e	244 e	243 e	241 e
90 cm bed + 3 rows	153 a	215 d	335 bc	352 bc	282 e	264 e	254 e	248 e	245 e	243 e	242 e
Conventional	160 a	250 bc	342 ab	360 ab	325 c	311 c	300 c	295 c	286 c	280 c	274 c

Figures in a column followed by different letters differ significantly at the 5% level by DMRT.

In second year, where wheat was sown in permanent beds, the planting method did not affect the number of tillers m^{-2} significantly at the beginning (20 DAS) and with the advancement of days, the differences were significant. At 30 DAS, the highest number of tillers m^{-2} was recorded in 70 cm beds with three plant rows. At 40 and 50 DAS, the tiller production in conventional method and 70 cm beds with both two and three rows were statistically identical. From 60 to 120 DAS, the 70 cm beds with three rows produced significantly the highest number of tillers m^{-2}. This was the lowest in 90 cm beds with two rows. These tiller productions obviously matched up with the number of panicles m^{-2}, and which might be contributed to the grain yield of corresponding method. The results also indicated that the bed planting with narrow beds were able to compensate the number of tillers m^{-2} for blank spaces between beds while the wider one did not. In every treatment the number of tillers m^{-2} increased very rapidly in early stages and reached to the highest at 50 DAS and then started declining due to death of some tillers and at later stages it became more or less stable, which indicated that the maximum tillering of wheat might be occurred in between 40 and 60 DAS.

Leaf area index (LAI)

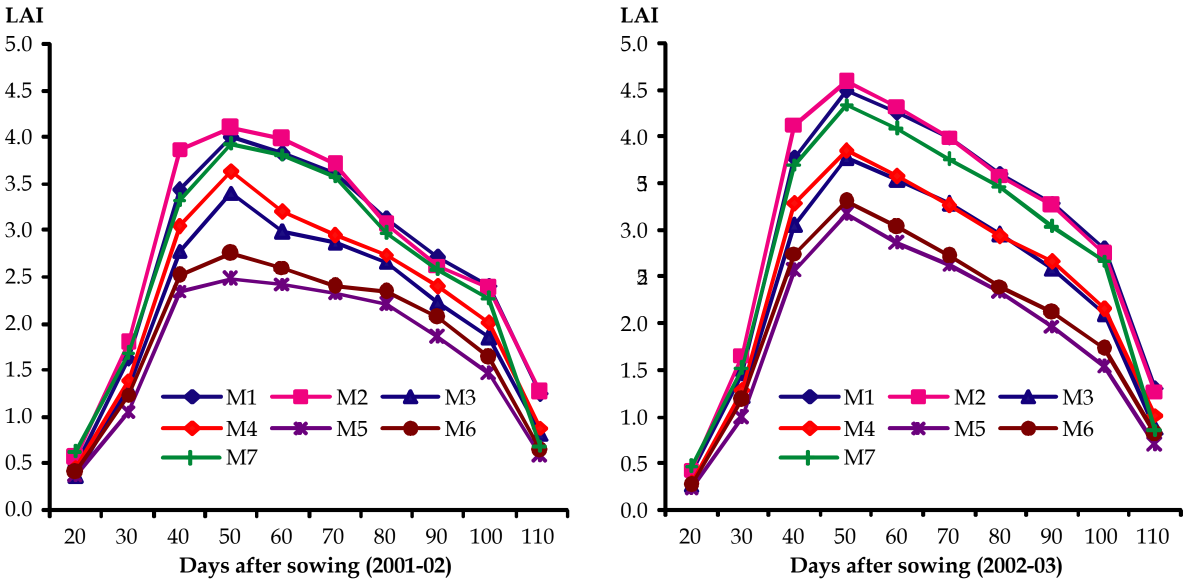
In the first year, at 20 DAS, the highest LAI was recorded in the conventional method. At 30 DAS the highest LAI was found in 70 cm beds with three plant rows followed by 70 cm beds with two rows and conventional method (Fig.1). This trend was continued up to 90 DAS and at the later stages (100-110 DAS), 70 cm beds with both two and three rows gave similar LAI, which were higher than the conventional method and rest of the bed planting treatments. Among the bed planting treatments, the 70 cm beds irrespective of plant row resulted in the highest LAI and with the increase in width of beds, the LAI was decreased throughout the growing period. Three plant rows per bed produced higher LAI than two plant rows per bed under same width bed width, which might be due to higher number of tillers m^{-2}. In the second year, the results showed very similar pattern to that of first year.

At early the stage of crop growth, the LAI increased rapidly and reached the maximum at 50 DAS for all the treatments. From 60 DAS, it started decreasing, which was continued up to the maturity. The narrow beds (70 cm) were able to produce LAI as much as conventional method or even higher than conventional method at mid to later stage of crop growth while the wider beds (80 and 90 cm) failed to do so. At maturity stage (110 DAS), the crop was greener in bed planting, especially in narrow beds, than conventional method resulting higher LAI, while it was sharply decreased in conventional method.

Simple linear regression analysis of LAI at different growth stages with grain yield of wheat showed that the relationship was significant in both the years (Fig. 2). However, the value of coefficient of determination at CRI stage (20 DAS) was low (R^2 = 0.23–0.44). The significant linear relationship of the LAI at heading (50 DAS), grain filling (80 DAS) and ripening (110 DAS) stages with grain yield (R^2 = 0.59–0.88) indicated that the grain yield was increased with increasing LAI. Therefore, the higher LAI in bed planting with 70 cm bed at the later stages of crop growth might be a reason for higher grain yield.

Dry matter production (DMP)

Planting method significantly affected the DMP (shoot) of wheat at different DAS in both the years. In first year, at preliminary stage (20 DAS), the conventional and 70 cm beds with three rows produced similar dry matter yield, which was significantly higher than the rest of the treatments (Table 2). At 30 DAS 70 cm beds with both two and three rows, 80 cm beds with three rows and conventional method produced alike dry matter yield. This trend was continued up to 60 DAS. During 70 to 90 DAS, 70 cm beds with both two and three rows and conventional method recorded statistically similar DMP. From 100 to 120 DAS, 70 cm beds



M1 = 70 cm bed + 2 rows, M2 = 70 cm bed + 3 rows, M3 = 80 cm bed + 2 rows, M4 = 80 cm bed + 3 rows, M5 = 90 cm bed + 2 rows, M6 = 90 cm bed + 3 rows, M7 = conventional

Fig. 1. Leaf area index of wheat under different methods of planting at different days after sowing.

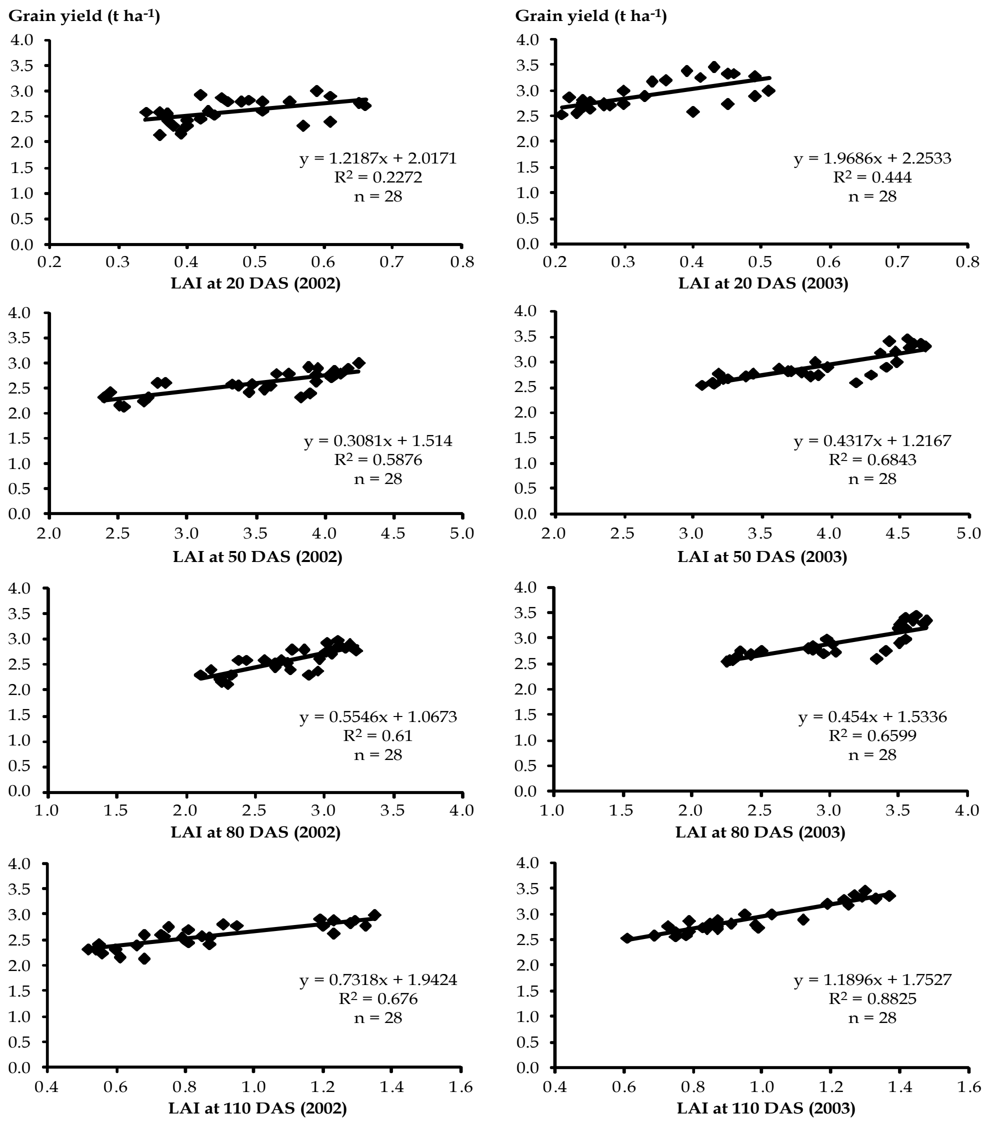


Fig. 2. The relationship between LAI at different stages of crop growth and grain yield of wheat.

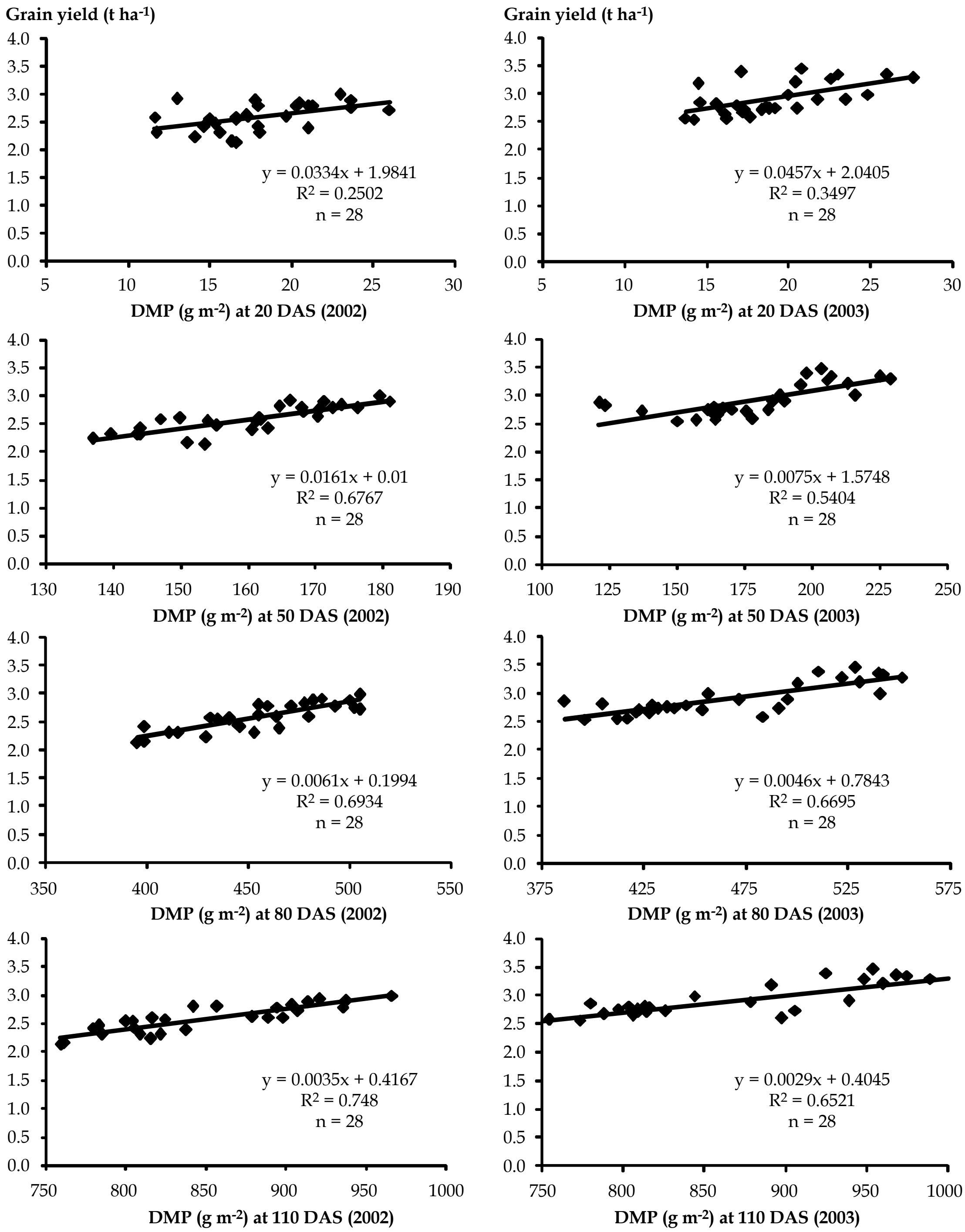


Fig. 3. The relationship between DMP at different stages of crop growth and grain yield of wheat.

with both two and three rows produced significantly higher dry matter yield than conventional method. Higher DMP of wheat under raised bed planting than conventional method was also reported by Khaleque *et al.* (2008). The similar pattern of DMP was observed in second year, in permanent beds.

Figure 3 illustrated simple linear regression analysis of DMP at CRI (20 DAS), heading (50 DAS), grain filling (80 DAS) and ripening (110 DAS) stages with grain yield of wheat. The relationship was significant in both the years. The linear relationship indicated that the grain yield was increased with increasing DMP. Therefore, the higher DMP in bed planting with 70 cm bed, especially at heading, grain filling and ripening stages might be a reason for higher grain yield (R^2 = 0.54–0.75).

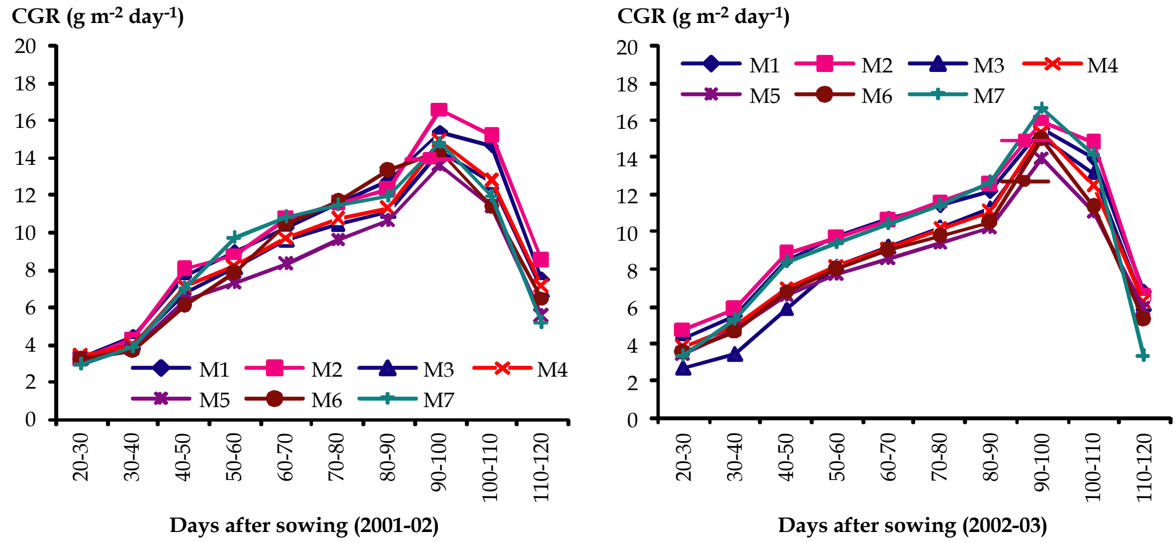
Table 2. Dry matter production (DMP) of wheat under different planting methods at different days after seeding (DAS.

Planting method	DMP (g m^{-2}) at different DAS										
	20	30	40	50	60	70	80	90	100	110	120
						2001-02					
70 cm bed + 2 rows	18b	51abc	95ab	171ab	261ab	363ab	479a	607a	761ab	908a	977b
70 cm bed + 3 rows	21a	53a	97a	177a	265a	372a	488a	611a	778a	929a	1014a
80 cm bed + 2 rows	15d	49cd	89bcd	157bc	238bcd	334c	438b	550d	699d	812d	867ef
80 cm bed + 3 rows	18bc	51ab	91abc	162abc	245abc	342bc	450b	563cd	707d	820cd	885de
90 cm bed + 2 rows	15d	47d	85d	148c	221d	304d	401c	507e	644e	771e	846f
90 cm bed + 3 rows	17c	49bcd	86cd	147c	226cd	331c	447b	580bc	724cd	853bc	923c
Conventional	22a	52ab	91a-d	161abc	258ab	366ab	481a	600ab	749bc	868b	920cd
						2002-03					
70 cm bed + 2 rows	19cd	62b	116b	201b	299ab	405ab	520ab	641ab	796a	935a	1002a
70 cm bed + 3 rows	24a	72a	130a	218a	314a	420a	536a	661a	821a	968a	1034a
80 cm bed + 2 rows	17de	43e	77e	136e	218e	309e	411d	523d	674c	805c	866d
80 cm bed + 3 rows	19bc	57bc	107c	176c	258c	349c	450c	560c	714b	838b	900c
90 cm bed + 2 rows	15e	49d	96d	162d	238d	324de	417d	520d	659c	770d	828e
90 cm bed + 3 rows	18cde	53cd	99cd	167cd	246cd	336cd	433cd	538cd	687bc	801cd	853de
Conventional	22ab	55c	107c	191b	285b	388b	502b	628b	795a	936a	969b

Figures in a column followed by different letters differ significantly at the 5% level by DMRT.

Crop growth rate (CGR)

In the first year, the bed planting in 70 cm bed with both two and three rows always resulted in higher CGR than conventional and other bed planting treatments (Fig. 4). The wider beds (80 and 90 cm) gave lower CGR than conventional method except at very early and very later stages of crop growth, where conventional method gave the lowest. In the second year, during 20-30 DAS, the highest CGR was recorded in 70 cm beds with three rows, which was followed by the same bed width with two rows. However, CGR of these two treatments during 30-40 DAS were comparable. During 40-50 to 100-110 DAS, CGR in 70 cm beds with both two and three rows and conventional method were comparable. However, at the final stage (110-120 DAS) all the bed planting treatments resulted in higher CGR than conventional method. From the two years results it was revealed that the CGR in narrow beds (70 cm) was either comparable or higher than conventional method and in wider beds (80 and 90 cm), it was lower in most of the cases. The CGR of different treatments correspond the grain yield of the respective treatments.



M1 = 70 cm bed + 2 rows, M2 = 70 cm bed + 3 rows, M3 = 80 cm bed + 2 rows, M4 = 80 cm bed + 3 rows, M5 = 90 cm bed + 2 rows, M6 = 90 cm bed + 3 rows, M7 = conventional

Fig. 4. Crop growth rate of wheat under different methods of planting at different days after sowing.

Agronomic productivity

The highest grain yield was recorded in 70 cm wide beds with two plant-rows bed^{-1}, which was statistically equal with the grain yield of 70 cm wide beds with three plant-rows bed^{-1} and higher than conventional method and 80 and 90 cm wide beds with both two and three plant rows (Table 3). Similar results by bed planting in wheat was also reported by Dhillon *et al.* (2000), Gupta *et al.* (2000), Connor *et al.* (2003b), Sayre (2003), Hossain *et al.* (2004), and Meisner *et al.* (2005). Grain yield was higher in narrow bed (70 cm) and with the increase in bed width, yield was decreased. There was no significant yield difference between three and two plant-rows bed^{-1}. The highest yield in the bed planting with 70 cm beds were attributed to higher number of panicles m^{-2}, grains panicle^{-1} and 1000-grain weight (Table 3). In spite of similar number of panicles m^{-2} in conventional and 70 cm bed, the grain yield of conventional method was lower due to lower number of grains panicle^{-1} and lower grain weight.

Table 3. Grain yield and yield components of wheat under different methods of planting.

Planting method	Yield and yield components							
	2001-02				2002-03			
	Grain yield (t ha^{-1})	Panicle m^{-2} (no.)	Grain panicle^{-1} (no.)	1000-grain wt. (g)	Grain yield (t ha^{-1})	Panicle m^{-2} (no.)	Grain panicle^{-1} (no.)	1000-grain wt. (g)
70 cm bed + 2 rows	2.85 a	306 a	34.3 a	42..3 a	3.34 a	310 a	36.3 a	42.3 a
70 cm bed + 3 rows	2.82 a	312 a	32.0 b	41.7 a	3.28 a	325 a	33.8 b	41.9 a
80 cm bed + 2 rows	2.54 bc	231 c	34.2 a	41.3 a	2.78 bc	260 c	35.9 a	41.5 a
80 cm bed + 3 rows	2.65 b	244 b	31.1 c	41.4 a	2.87 b	282 b	32.9 c	41.5 a
90 cm bed + 2 rows	2.26 d	219 c	34.2 a	41.9 a	2.64 c	241 d	36.0 a	42.1 a
90 cm bed + 3 rows	2.43 c	231 c	31.3 bc	41.5 a	2.67 bc	242 d	33.0 c	41.7 a
Conventional	2.35 dc	305 a	27.3 d	39.2 b	2.81 bc	274 bc	28.3 d	39.6 b

Figures in a column followed by different letters differ significantly at the 5% level by DMRT

CONCLUSIONS

In raised bed planting with narrow beds (70 cm), different crop growth parameters such as total tiller production, LAI, DMP and CGR were similar or higher than conventional method at different growth stages of wheat. Agronomic productivity of wheat could be increased by bed planting with 70 cm bed in rice-wheat cropping system.

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