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Impact of Planting Density and Growth Habit of Genotypes on Wheat Yield under Raised Bed Planting Method

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Abstract: Wheat planting on raised beds is considered to improve wheat productivity and reduce crop lodging in the poorly drained soils of rice-wheat cropping system. Hence, multi-location farmers' field trials were conducted with the objectives to determine optimum seed rate and performance of different wheat cultivars on raised beds. The results showed that varying quantities of seed rates (75, 100 and 125 Kg ha^{-1}) had no effect on grain yield and yield contributing components of wheat crop planted on raised beds. It means, lower seed rate of 75 kg ha^{-1} can produce comparable yields in bed-planted wheat. Likewise, three wheat cultivars, viz; Auqab-2000, Inquilab-1991 and Chenab-2000, with semi erect growth habit and other three wheat cultivars Wattan-1994, Bhakkar-2001 and Wafaq-2001, with erect growth habit were tested on beds in both years. Biological and grain yield of variety Aquab-2000 was higher on beds in comparison to other varieties in both years. The study revealed that wheat cultivars with semi erect growth habit performed better on beds than the cultivars with erect growth habit. Furthermore, cultivar Aquab-2000 performance was better than other semi erect growth habit varieties.

Key words: Wheat yield, Seeding density, Genotypes, Raised beds, Rice-wheat system.

INTRODUCTION

Wheat is predominantly cultivated on an area of 1.40 million hectare in rice-wheat cropping system of Punjab. However, grain yield is largely affected by late planting, poor crop stand, low fertility, poor drainage conditions, water scarcity, weeds infestation and lodging. The adoption of zero till wheat technology has given a suitable option to farmers to avoid late planting of wheat crop and helped in improvement of crop stand and weed control to some extent (Hobbs and Gupta., 2003; Hussain *et al*., 2003; Majeed *et al*., 2015).

In rice-wheat system, puddling operations and continuous flooding of soil for rice crop results in development of plow pan and reduces water percolation (Hobbs, 2003) that causes poor drainage and water logging during wet winters. Wheat fields are irrigated through flood irrigation that is a simple but not efficient technique in this area. Due to uncertainty and limited water availability at critical growth stages, the technique provides improvement in irrigation and nutrient management, saving in water, crop stand, lower seed rate and reduction in lodging (Mollah *et al.,* 2015).

Raised bed planting system allows better stand establishment, uses less seed rate, provides opportunity for mechanical weed control, permits band application of fertilizers, reduces crop lodging, provides drainage where water logging occurs (Sayre, 1998). According to Hobbs *et al* (1998), wheat was planted on beds to improve water dissemination and efficiency. Wheat sown on beds produced good yield, due to better grains per spike in rice-wheat system (Mann *et al*., 2003). Raised bed planting system has the option to control weed through cultivation of the furrows. Furthermore, it improved yield through reduced lodging associated directly and enhanced yield indirectly through reduced harvest losses (Sayre, 1998).

In bed planting, wheat grown in two to three rows on a bed is practicable; nevertheless, all wheat varieties were not suitable for bed planting. It is important to categorize appropriate wheat varieties for bed planting (Sayre and Moreno Ramos, 1997). In Mexico, short stature and upright growth habit varieties (Yecora 70, Oasis 86, and Super Kauz 88) were not appropriate to bed planting. However, Borlaug 95, a short and upright variety was better adapted to bed planting (Sayre *et al*., 2008). Wheat

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cultivars, such as, PBW154 and HD2329 with an upright structure, were not high yielding on beds, as they were not able to compensate gap between beds. However, wheat variety, such as, PBW226 with spreading structure, was able to compensate gaps and was well adapted on beds (Hobbs and Gupta, 2003).

An important first step in starting research on raised beds, wheat planting is to assess a wide range of cultivars with varying height, tiller formation ability phonologies and canopy architectures (Sayre, 1998). Bed planting adapted genotypes had 50% less lodging as compared to flat planting. The reduction in lodging was due to a thicker stem on bed, as compared to flat planting method and a variety interaction may be exploited to get maximum grain yield (Tripathi *et al*., 2005).

Moreover, wheat planting on raised beds could also reduce seed rate and minimize the cost of production (Sayre and Moreno Ramos, 1997). There were no significant variances in grain yield noticed between seed rates of 100 and 50 kg ha^{-1} for many bed-planted wheat cultivars in Mexico. A reduction in seed rate of wheat genotypes on raised beds may be attributed to better emergence (Limon-Ortega *et al*., 2000). In this study, on-farm trials were conducted at different locations, during 2002-2004, with the objectives to determine optimal seed rate of wheat planted on raised beds and to evaluate the response of different wheat genotypes with raised bed planting technique.

MATERIALS AND METHODS

The trials were conducted during 2002-03 and 2003-2004, during wheat crop growing seasons on farmer's fields at 5 sites, representing the conventional rice-wheat belt (District Sheikhupura) of Punjab. The soils of the sites were deficient in nitrogen and phosphorus at pH 7.5 and electrical conductivity of 0.4–0.5 dS/m. The rice variety 'Super Basmati' was grown as summer season crop. After rice harvesting, the fields were prepared with disk harrow and repeated cultivator with planking. A fertilizer dose @ 120-80 Kg NP ha^{-1} in the form of diammonium phosphate (DAP) and urea was applied in this trial. Nitrogen fertilizer was applied in two splits (basal and first irrigation), while, all phosphorus was applied as basal dose. Wheat was planted with Bed and Furrow Shaper/Planter with two rows on each bed. The distance from top of one bed to other bed was 75 cm. There were three seed rates of 75, 100 and 125 Kg ha^{-1}, for raised-bed planted wheat crop, during both seasons. During 2002-03, wheat varieties, Auqab-2000, Chenab-2000, Inquilab-91, and Wattan, were planted, whereas, Auqab-2000, Bhakkar-2001, Inqlab-91, and Wafaq-01, were planted during 2003-04. Wheat sowing was done on normal planting time during both seasons. Weeds were controlled by the application of appropriate herbicides. The fields were irrigated according to the requirement. The crop was harvested at physiological maturity and data, regarding yield and yield components, was recorded.

Statistical Analysis System (SAS) computer software was used for statistical analysis of parameters (SAS Institute, 1995). General Linear Model (GLM) procedures were adopted for Analysis of variance and LSD.

RESULTS AND DISCUSSION

Effect of seed rate on growth and yield: Plant population and fresh biomass varied among different planting densities. Higher seed rate (125 Kg ha^{-1}) produced significantly higher plant population and biomass, as compared to low seed rates of 75 and 100 Kg ha^{-1}, with better growth during tillering to heading stage. There was no significant variation in fresh biomass of wheat among different seed rates (Table 1).

Table 1: Effect of different planting densities on germination and fresh biomass of wheat in 2002-03.

Seed rate (Kg ha^{-1})	Germination (Plants m^{-2})	Fresh biomass 46 days after planting (Kg m^{-2})	Fresh biomass 119 days after planting (Kg m^{-2})
75	82 b	0.09 b	3.56 a
100	87 b	0.09 b	3.68 a
125	97 a	0.11 a	3.55 a
Mean	89	0.096	3.59

Means within the same column followed by the same letter are not significantly different at $P \leq 0.05$.

During the first season (2002-03), number of spikes was significantly higher ($p<0.05$) with the higher seed rate at 125 Kg ha^{-1} (Table 2), but these spikes were small and tillers were weak. On the other hand, the spike length was significantly higher with lower seed rate of 75 Kg ha^{-1}, as compared to other higher seed rates (Table 2). No differences in spikelets per spike and thousand-grain weight due to seed rate were observed. Plant height was not significantly affected by seed rate. Although, the biological yield was higher with high seed rate but the differences were statistically non-significant, whereas, better growth and grain filling resulted non-significantly higher grain yield with lower seed rate (Table 2). The results supported that there were no grain yield differences even with lower seed rates in raised bed planted wheat.

During 2003-04, number of spikes was significantly higher with seed rate of 100 Kg ha^{-1} in comparison with other seed rates of 75 and 125 Kg

ha^{-1} (Table 3). However, non-significant differences in yield components, e.g., spike length, spikelets per spike and plant height, were noted due to different seed rates (Table 3). These non-significant differences in yield components resulted in statically at par with biological and grain yields with three different rates.

Table 2: Effect of different planting densities on growth and yield of wheat crop in 2002-03.

Seed rate (Kg $ha^{-1)}$	Tillers per m^2	Plant height (cm)	Spike length (cm)	Spikelet per spike (No.)	1000-grain weight	Bio. yield (Kg ha^{-1})	Grain yield (Kg ha^{-1})
75	304 b*	93 a	9.5 a	17 a	41 a	11887 a	3940 a
100	316 b	92 a	9.1 b	17 a	40 a	11632 a	3745 a
125	347 a	93 a	8.9 b	17 a	41 a	12041 a	3896 a
Mean	322	92	9.1	17	41	11853	3863

Means within the same column followed by same letter are not significantly different at $P \leq 0.05$.

Table 3: Effect of different planting densities on growth and yield of wheat crop in 2003-04.

Seed rate (Kg ha^{-1})	Tillers per m^2	Plant height (cm)	Spike length (cm)	Spike lets per spike (No.)	1000-grain weight	Biological yield (Kg ha^{-1})	Grain yield (Kg ha^{-1})
75	218 b	82 a	10.9 a	19 a	34 b	8069 a	2920 a
100	235 a	84 a	11.2 a	19 a	35 a	8411 a	3133 a
125	227 b	82 a	10.9 a	19 a	36 a	7975 a	2857 a
Mean	227	83	11.0	19	35	8152	2970

Means within the same column followed by the same letter are not significantly different at $P \leq 0.05$.

It may be concluded from these results that wheat crop yields on raised bed were higher in the first season (2002-03), as compared to the second season (2003-04), due to favorable climatic conditions (good rainfall of 179 mm rainfall and comparatively low temperature), whereas, only a total of 75 mm rainfall was received during 2003-04 growing season with comparatively higher temperature. Higher temperature, during grain formation period, resulted in lower 1000-grain weight in 2003-04 (34-35 g), as compared to 2002-03 (40-42 g).

Further, the results of two growing seasons at different sites revealed that different seed rates of 75,100 and 125 Kg ha^{-1} did not have any significant effect on plant height, number of spikes, spike length, 1000 grain weight of wheat that ultimately resulted in non-significant differences in grain yield of wheat. It showed that better growth and tillering on raised beds can produce better yields even with lower seed rates. These results are in conformity with Sayre and Moreno Ramos (1997) and Limon-Ortega *et al*. (2000), who also reported no significant differences in grain yield, while comparing seed rates of 100 and 50 kg ha^{-1} for several beds planted bread wheat genotypes in Mexico. The results supported that there were no grain yield differences even with lower seed rates in raised bed planted wheat, therefore, the seed rate of 75 Kg ha^{-1} can be recommended for wheat planted on raised beds.

Effect of raised bed planting on growth and yield of wheat cultivars: In this trial, six different wheat cultivars were tested for their performance on raised beds with different growth habits (Table 4). All of these wheat cultivars had plant height in the range of 95-106 cm and tillering capacity of 104-155/m row (Table 4).

Table 4: Characteristics of wheat cultivars planted in 2002-03 and 2003-04.

Variety	Growth habit	Tillers per m row (No.)	Height (cm)
Auqab-2000	Semi erect	104	106
Inquilab-1991	Semi erect	155	105
Chenab-2000	Semi erect	116	95
Bhakkar-2001	Erect	116	101
Wattan-94 / V-87094	Erect	106	95
Wafaq-2001	Erect	84	110

In 2002-3 growing season, wheat cultivar "Auqab-2000" had higher biological and grain yield in comparison to other cultivars (Chenab-2000, Inquilab-1991 and Wattan-94) (Table 5). Auqab-2000 had better tillering, spike length and growth on raised bed compared to other wheat cultivars. In addition, no lodging was observed in all varieties on raised bed. However, in some other trials at NARC, lodging was

observed in Auqab-2000 and Inquilab-91 with flat sowing.

Table 5: Yield and yield components of different wheat cultivars on raised bed in 2002-03.

Variety / Genotype	Plant height (cm)	Spikes per m^2 (No.)	Spike length (cm)	Spikelets per spike (No.)	Bio. yield (Kg ha^{-1})	Grain yield (Kg ha^{-1})
Chenab-2000	88 c*	312 c	8.33 c	16.63 c	3918 ab	12065 b
Inquilab-91	93 b	331 b	9.79 a	17.22 b	3814 ab	11198 c
Auqab-2000	100 a	364 a	9.62 a	18.18 a	4020 a	12785 a
Wattan-94	89 c	283 d	8.85 b	15.29 d	3689 b	11368 c

Means within the same column followed by the same letter are not significantly different at $P \leq 0.05$.

Wheat varieties, Auqab-2000, Chenab-2000 and Inquilab-1991, have semi-erect growth habit and had more number of tillers, biological and grain yield, as compared to wheat cultivar Wattan-94 with erect growth habit. Wheat cultivars with an upright structure were not high yielding on beds as they were not able to compensate gap between beds, however, wheat variety with spreading structure was able to compensate gaps and was well adapted on beds (Hobbs and Gupta, 2003). From three semi-erect growth habit cultivars, the performance of Aquab-2000 was better in term of yield, tillers and plant height. This can be explained that sometimes varieties with the same growth habit and stature could perform differently on beds. In Mexico, short stature and upright growth habit cultivars (i.e., Yecora 70, Oasis 86, and Super Kauz 88) were not suitable to bed planting. However, Borlaug 95, a short and upright cultivar, was suitable to bed planting (Sayre *et al*., 2008).

During 2003-04, wheat cultivar, Auqab-2000 had higher number of tillers, wheat grain and biological yield than other wheat cultivars (Table 6). Wheat grain yield was the highest with Aquab-2000 that followed in order of Inquilab-91, Bhakkar-2000 and Wafaq-01. In this year, Auqab-2000, a variety with semi-erect growth habit, outperformed all other wheat cultivars, due to its better growth and tillering ability. Grain and biological yield of wheat cultivars with erect growth habit, Bhakkar-01 and Wafaq-01, was lower than Inquilab-91 and Auqab-2000 (Table 6).

Table 6: Yield and yield components of different wheat cultivars on raised bed in 2003-04.

Variety / Genotype	Plant height (cm)	Spikes per m^2 (No.)	Spike length (cm)	Spike lets per spike (No.)	Bio. yield (Kg ha^{-1})	Grain yield (Kg ha^{-1})
Inquilab-1991	81 b	221 b	11.3 a	18.3 b	2991 b	7974 b
Auqab-2000	87 a	247 a	11.0 ab	19.5 a	3152 a	9189 a
Bhakhar-2001	77 c	239 a	11.0 ab	17.3 c	2869 c	7633 b
Wafaq-2001	85 a	200 c	10.9 b	19.9 a	2861 c	7811 b

Means within the same column followed by the same letter are not significantly different at $P \leq 0.05$.

Results from these trials revealed that during two wheat growing seasons, wheat cultivar Auqab-2000 had higher grain and biological yield on raised beds than other wheat cultivars and it had better growth and tillering that mainly contributed towards its higher yield. In addition, wheat cultivar, Auqab-2000, did not experience any lodging that was seen on flat sowing generally. It might be due to better development of stem on bed that helped in reduction in lodging significantly and improved its yield. Biological and grain yield of variety "Aquab-2000" was higher on beds in comparison with the other varieties, such as, Chenab-2000, Inquilab-1991, Bhakkar-2001, Wattan-1994 and Wafaq-2001 in both years. Wheat varieties with semi-erect growth habit performed better on raised beds and had better tillering capacity, height and did not lodge. On the other hand, wheat cultivars, like Bhakkar-2001, Wafaq-2001 and Wattan-1994, that had erect growth habit, did not perform well on the raised beds.

CONCLUSION

Bed planting, a resource conservation technique, provided better drainage during growing season and reduced lodging in wheat crop. It was concluded from these trials that there were no grain yield differences even with lower seed rates in raised-bed planted wheat, therefore, the seed rate of 75 Kg ha^{-1} can be used for wheat planted on raised beds. The results of the trials showed that the selection of cultivars was an important aspect in wheat production on raised bed.

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