Research Article

Effect of irrigation levels and bed-system of planting on seed fill duration, seed growth rate, yield and yield components of spring wheat (*Triticum aestivum*) under semiarid condition

Khair Muhammad Kakar*, Amanullah and Asif Iqbal

Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar-25130

*Corresponding author's email: agrarian786@yahoo.com

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Abstract

A field experiment was conducted to study the impact of irrigation levels (I2 = 2-Irrigation, I3 = 3-Irrigation, I4 = 4-Irrigation, I5 = 5-Irrigation) and bed-system of planting (P1 = Flat planting in rows, P2 = Flat planting 3rd row skip, P3 = Bed planting broadcast on beds and P4 = Bed planting 3 rows on beds) on wheat. The experiment was conducted at the Agronomy Research Farm of The University of Agriculture Peshawar, for two years during 2001-02 and 2002-03. The experiments were designed in RCBD with split plot arrangements. Data were recorded on number of productive tillers m^{-2} , seed fill duration, mean seed growth rate, number of grains spike $^{-1}$, thousand grains weight (g) and grain yield ($kg\ ha^{-1}$). The results revealed that productive tillers m^{-2} , number of grains spike $^{-1}$, seed growth rate, thousand grains weight and grain yield $kg\ ha^{-1}$ was significantly affected by planting methods and irrigation levels. The plot irrigated five times produced more productive tillers m^{-2} , more grains spike $^{-1}$, seed growth rate, thousand grains weight and grain yield $kg\ ha^{-1}$. Highest grain yield ($5294\ kg\ ha^{-1}$) were noted in plots of 3 rows on beds as well as 3 rows on beds irrigated five times produced highest grain yield comparatively. It was concluded from this study that bed planting method 3 rows on beds along with five irrigations could increase yield and yield components of spring wheat under semiarid climate.

Keywords: Planting methods; Irrigation; Wheat; Grain yield ($kg\ ha^{-1}$)

Introduction

Wheat is the most important cereal crop in the world and also in Pakistan. It is the major staple food for the people of Pakistan that fulfill 95% of the food requirements of the

country [1]. It contributes 10.1% to the value added in agriculture and 2.2% to the gross domestic product, and was cultivated over an area of 8,693,000 ha during 2012–2013 [2]. Wheat as a Rabi (winter) crop is usually

planted either by drilling the seed in rows while maintaining a row-to-row distance of 22.5 or by broadcasting the seed shallow tillage following planking and flood irrigation, especially in irrigated areas. Despite its high yield potential, yield ha^{-1} is very low in Pakistan compared to that in other wheat producing countries [3].

Better irrigation and soil management technologies are needed to improve water and fertilizer use efficiency. These resource conservation technologies include mainly bed planting of wheat, sowing of wheat using zero tillage, and laser land leveling of fields. Bed planting system facilitates mechanical cultivation as an alternative method of weed control during the crop growing season. It also provides an opportunity for hand weeding and irrigation water management is more efficient, with less labor required with the use of furrows than with conventional flood irrigation [4, 5]. A study by concluded that raised bed planting decreased water consumption, increased water use efficiency, and had higher yields than flat planting in winter wheat [6]. It is found that bed planted wheat offered crop rotation opportunities and field-access flexibility for fertilizer application and weed control [7]. The role bed planting may play important role in areas where water is a limiting factor, hence the application and adaptation of permanent beds increase its feasibility [8]. In 1999-2000, about 40% less water was made available from the canal system of Punjab and Sindh for wheat production. There are reports that bed planting can produce good yield with less water. To coup with water scarcity, the government of Pakistan recommended bed planting for wheat. The recommendation may have been based on some work in the country, work in other countries and rapid adoption of technology in some of the countries like Mexico [9]. Hence, data from a well-planned experiment on effect of irrigation levels under conventional and bed system of planting is

required to quantify the effect of irrigation under the bed system of planting for wheat [10].

Water is one of the most important factors that are necessary for proper growth, balanced development and higher yield of all crops. Water deficiency affects plant growth and grain yield. it is investigated the effect of water stress on grain growth pattern and yield responses of wheat and found that 94% of tillers of irrigated plants produced ears, compared to 79% of the stressed plants [11, 12; 13]. Grain yield was reduced to 65% in the stressed plants compared to that of irrigated plants. [14] Reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages. It was pointed out that irrigation is an expensive input therefore; farmer, agronomist, economist and engineer need to know the response of yield to irrigation. Water is the most important factor that is necessary for proper growth, balanced development and higher yield of all crops including wheat. To fulfill their obligation of providing adequate food for human beings and their livestock, the agricultural scientists and researchers must find ways to utilize all the natural resources efficiently, including water for crop production. Greater efforts are needed to increase water use efficiency in crop production due to the recent drought and the fact that fresh water is becoming scarcer and scarcer as well as costlier and costlier competition for water between agricultural and non-agricultural enterprises continuously increase and the non-agricultural enterprises can pay more for fresh water [15].

The important aspects of research needed to make a realistic decision to change from conventional to bed system of planting for sustainable higher yield of wheat under water shortage, have provided the basic idea for this research. This study was initiated with the objectives of comparing the two systems of

planting under different levels of irrigation. Keeping in view the vital change i.e. the newer system of bed planting gave us good yield of wheat with less water, with relevancy of proper level of irrigation for the new planting system [16].

Materials and Methods

The experiment titled "Effect of Irrigation Levels (I_2 = 2-Irrigation, I_3 = 3-Irrigation, I_4 = 4-Irrigation, I_5 = 5-Irrigation) under Bed-System of Planting (P_1 = Flat planting in rows, P_2 = Flat planting 3rd row skip, P_3 = Bed planting broadcast on beds, P_4 = Bed planting 3 rows on beds) on Wheat" was conducted at Agronomy Research Farm of The University of Agriculture Peshawar, for 2-years during 2001-02 and 2002-03. The experiment was performed in randomized complete block design having four replications. Main plot size of 14.4 m x 27 m and sub-plot size 3.6 m x 6 m was used. Planting system & irrigation levels ($4 \times 4 = 16$) combinations were allotted to main-plots, while irrigation levels were allotted to sub-plot. Detailed of the treatments are "Planting methods: P_1 = (Rows 30 cm apart in case of flat planting), P_2 = (30 cm apart rows 3rd row skip, in case of flat planting), P_3 = (3-beds in case of bed-planting. 90 cm bed and broad cast on beds), P_4 = (3-beds in case of bed-planting. 90 cm bed and 3 rows on beds)". "Irrigation schedules: I_2 = 3rd week after emergence + irrigation at Boot stage, I_3 = 3rd week after emergence + irrigation at boot stage + Milk stage, I_4 = 3rd week after emergence + Tillering + Irrigation at anthesis + Milk stage, I_5 = 3rd week after emergence + irrigation at jointing + Boot + Anthesis + Milk." The experimental plot was irrigated and at proper moisture level the land was thoroughly prepared. The recommended dose of NPK (120:90:60 kg ha⁻¹) were applied as basal dose. Full dose of P and K and half of N dose were applied and mixed with the soil during seed bed preparation. The remaining half of the N-dose was applied with first irrigation. Sowing was

done in 2nd week of November using variety Fakhri-e-Sarhad. Data were recorded on the following parameters (number of productive tillers m⁻², seed fill duration, mean seed growth rate, number of grains spike⁻¹, thousand grains weight (g) and grain yield (kg ha⁻¹). Two representative rows were selected in each experimental unit. Numbers of productive tillers were counted in the selected rows. Productive tillers m⁻² was calculated from the number of productive tillers counted and the area sampled. Seed fill duration was calculated by using the formula i.e. Days to maturity (D.T.M) – Days to anthesis (D.T.A) = S.F.D. Mean seed growth rate (MSGR) was calculated by using the following formula:

$$\text{MSGR} = \text{Thousand grain weight} \div \text{Seed fill duration}$$

Ten representative spikes were selected from each experimental unit. The grains were separated and counted to record data on grains per spike. For thousand grains weight data; after threshing, 1000 grains was counted from each plot and weighed with the help of electronic balance. The six rows harvested were threshed. The grains were cleaned, dried and weighted to record the grain yield and then grain yield kg ha⁻¹ was calculated.

Results and Discussion

Productive Tillers (m⁻²)

Data regarding number of productive tillers m⁻² of wheat as affected by planting methods and irrigation levels are reported in Table 1. Analysis of each of the individual and combined two years data of number of productive tillers m⁻² indicated that planting methods and irrigation levels had significant effect on number of productive tillers m⁻², while their interaction was not significant. The number of productive tillers m⁻² increased with the increase in number of irrigation up to 17 productive tillers m⁻² per irrigation. It is evident that planting method flat sowing in rows produced the highest

(444.19) numbers of productive tillers followed by bed sowing 3-rows (397.66) while the lowest (291.53) productive tillers m^{-2} was produced by bed sowing broadcast. Interaction of planting methods and irrigation levels show that there is a little increase in number of productive tiller m^{-2} with increase in number of irrigation under bed sowing broadcast, while in flat sowing in rows and bed sowing 3-rows there was comparatively more increase in productive tillers m^{-2} with increase in number of irrigations. The reason or logical justification could be fewer emergences in bed sowing broadcast and greater emergence in case of bed sowing 3-rows method. The planned comparison between the methods of planting revealed that sowing of wheat crop in lines or rows on beds produced significantly higher number of productive tillers m^{-2} as compared to wheat planted by broadcast on beds. This statement is partially in line with [17] who concluded that bed planting produced higher number of productive tillers when compared with broadcast on beds and flat planting methods. Significantly higher number of productive tillers m^{-2} was recorded in bed planting, while the least number of productive tillers m^{-2} was recorded in plots of Rabi drill sowing on flat [18].

Seed Fill Duration (Days)

Data regarding seed fill duration of wheat as affected by planting methods and irrigation levels are reported in Table 1. Perusal of the individual year data as well as two year combined data indicated that planting methods, irrigation levels and their interaction had no significant effect on seed fill duration. However, the interactions between years and irrigation levels and years and planting methods were significant at 5% of probability. Similarly the three factors interaction between years, planting methods and irrigation levels was highly significant. It is evident from the results that in 2001-02 bed planting 3 rows took the longest duration (38.50 days) for seed filling. While in 2002-03 bed planting broadcast took longer period (30.06 days). It may be due to differential effect of rainfall received and temperature prevailed throughout the growth period of crop under different planting methods and years; however the increase in irrigation levels in 2002-03 took minimum period to seed fill duration as shown in Fig. 1. Interaction between year and planting methods indicated that in 2002-03 bed planting 3 rows on beds took the longer duration for seed filling Fig. 2.

Table 1. Number of productive tillers m^{-2} , seed fill duration, mean seed growth ($\text{mg seed}^{-1} \text{ day}^{-1}$), number of grains spike $^{-1}$, thousand grains weight (g) and grain yield (kg ha^{-1}) of wheat as affected by planting method and irrigation levels.

Treatments	Number of productive tillers m^{-2}	Seed fill Duration	Mean seed growth rate ($\text{mg seed}^{-1} \text{ day}^{-1}$)	Number of grains spike $^{-1}$	Thousand grain weight (g)	Grain yield (kg ha^{-1})
Bed system of planting						
P1 (Flat-lines solid)	444.19	33.56	1.24	52.88	40.78	5018
P2 (Flat-skip rows)	380.16	33.75	1.33	51.72	44.06	4554
P3 (Beds-broadcast)	291.53	33.72	1.21	48.31	40.16	3505
P4 (Beds-lines solid)	397.66	34.03	1.36	53.75	45.41	5294
Significance	***	ns	**	**	**	***
Irrigations levels						
I2 (two irrigations)	350.41	34.03	1.2	43.59	39.69	4067
I3 (three irrigations)	372.5	33.84	1.27	46.22	42.09	4487
I4 (four irrigations)	386.75	33.56	1.31	56.5	43.31	4880

I5 (five irrigations)	403.88	33.63	1.37	60.34	45.31	4936
Significance	*	ns	**	***	**	**
Year-I	376.55	37.81	1.1	50.11	41.42	4475
Year-II	380.22	29.72	1.47	53.22	43.78	4711
Significance	ns	***	***	***	***	*
Planned comparison						
Flat Vs bed						
(P1+P2 Vs P3+P4)	***	ns	ns	*	Ns	**
Solid sowing Vs Skip						
(P1 Vs P2)	***	ns	*	ns	**	*
Broadcast Vs Lines on bed						
(P3 Vs P4)	***	ns	**	***	***	***
Y x P	ns	*	ns	ns	Ns	ns
P x I	ns	ns	ns	***	Ns	ns
Y x I	ns	*	***	*	Ns	ns
Y x P x I	ns	ns	ns	ns	Ns	ns

Figure 1. Interactive effect of year and irrigation levels on seed fills duration.

Figure 2. Interactive effect of year and planting methods on seed fill duration.

Seed Growth Rate ($\text{mg}^{-1} \text{ seed}^{-1} \text{ day}^{-1}$)

Data pertaining to seed growth rate of wheat as affected by planting methods and irrigation levels are presented in Table 1. Statistical analysis of the individual year data and two years combined data of seed growth rate revealed that planting methods and irrigation levels had significant effect on seed growth rate of wheat. While the interaction of planting methods and irrigation levels had no significant effect on seed growth rate of wheat. However the two-way interaction between year and irrigation levels had significant effect on seed growth rate of wheat. It is evident from the results that bed planting 3 rows on beds had the highest seed growth rate of 1.36 mg per seed per day followed by flat planting 3rd row skip with seed growth rate of 1.33 mg per seed per day. The lowest seed growth rate of 1.21 was noted in bed planting broadcast. The seed growth rate increased with an increase in irrigation from

I2 to I5. The reason to justify these results could be better soil and environmental condition including better light penetration leading to improved canopy photosynthesis. Interaction between year and irrigation levels indicated that in both year seed growth rate significantly increased with an increase in irrigation from I2 to I5; however in 2002-03 seed growth rate was maximum than 2001-02 as illustrated in [Fig. 3](#). Grain filling rate between irrigation levels were significant at all irrigation levels and increased with increasing number of days after anthesis up to 20 days [\[19\]](#). Grain filling rate in present study is in conformity to the finding of earlier researchers [\[20, 21\]](#). Grain filling rate in wheat is regulated by the current supply of photosynthates as well as remobilization of assimilates produced during vegetative stage. Post-anthesis soil drying results in accelerated leaf senescence which reduces current supply of assimilates to the grains [\[22, 23\]](#).

Figure 3. Interactive effect of year and irrigation levels on seed growth rate

Number of Grains Spike⁻¹

Data relating to number of grains spike⁻¹ of wheat as affected by planting methods and irrigation levels are shown in Table 1. Statistical analysis of data of each the individual and combined two years with respect to number of grains spike⁻¹ exhibited that planting methods, irrigation levels and their interaction had significant effect on number of grains spike⁻¹. Although interaction between year and planting methods was not significant yet year interacted with irrigation levels was significant. The number of grains per spike was higher in 2002-03 than 2001-02 which were 53.22 and 50.11 spikes respectively. The difference between flat and bed planting on the average was significant at 5% level of probability. The difference between solid sowing verses skip sowing was, however, not significant. Line sowing on beds produced significantly more grains spike⁻¹ (53.75) than broadcast on beds (48.31). The number of grains spike⁻¹ increased with increase in the number of irrigation [7]. The interaction between planting methods and irrigation levels revealed that there was much less differences among the planting methods when two irrigations were applied. This difference between the grains spike⁻¹ among the different methods of sowing was however greater when number of irrigation applied was increased. Increase in number of irrigations increased the number of grains (60.34). Similarly the line sowing on beds produced more grains (53.75) spike⁻¹ with the highest level of irrigation. Interaction of planting methods and irrigation levels showed that number of grains spike⁻¹ were maximum in bed planting with increasing irrigation levels upto I5 (Fig. 4). Interaction between year and irrigation levels indicated that number of grains spike⁻¹ increased in both years with maximum level of irrigation but this increase were more in 2002-03 as compared to 2001-02 (Fig. 5). Some

researcher concluded that grains spike⁻¹ increases with the adoption of bed planting system [17]. The reason could be the better light penetration and less water stress in plot which received the higher number of irrigation. It could be due to the drought that less numbers of grains were produced with the application of 2 irrigations. Highest number of grains spike⁻¹ was recorded in irrigation up to stem extension [24]. It was resulted that grains spike⁻¹ were found maximum when sowing was done according to triple-row bed planting [18]. This result is supported by the study which reported that bed planting showed significantly higher grains spike⁻¹ than conventional method [25, 26, 27; 28]. Researcher concluded that bed-planting increased the grains spike⁻¹ [29, 30].

Thousand Grains Weight (g)

Data concerning thousand grains weight (g) of wheat as affected by planting methods and irrigation levels are reported in Table 1. Statistical analysis of each of the individual year data as well as two years combined data on thousand grain weight depicted that planting methods and irrigation levels had significantly affected thousand grains weight while their interaction failed to reach the degree of significance. Planting methods bed planting 3-rows and flat planting 3rd row skip produced heavier grains 45.41 and 44.06 g respectively when compared with other planting methods. Thousand grains weight increased with increase in number of irrigations at the rate of 1.81g per thousand grains with one irrigation application. Results are in conformity with who reported that grain weight can be increased by increasing irrigation levels [13, 31; 32]. The heavier grains with line sowing on beds may be due to better light penetration in the canopy to the lower leaves. The lower leaves may have produced more assimilates for grain filling in case of line sowing on beds in skip row geometry. The lighter grains in

case of broadcast on beds may be due to poor growth and high weed infestation. Higher 1000-grains weight was observed in triple-row bed planting, while minimum 1000-grains weight was in plots sown by Rabi drill on flat [18]. It is reported that bed-planting increased thousand grains weight [29]. At the same time, in different studies it was resulted that planting methods for thousand grains weight were highest in the bed planting [25, 30].

Grain Yield (kg ha^{-1})

Grain yield in wheat is the ultimate goal towards which all the efforts are directed. Data regarding grain yield kg ha^{-1} of wheat as affected by planting methods and irrigation levels are presented in Table 1. Statistical analysis of the individual year as well as combined two years data on grain yield indicated that planting methods and irrigation levels had significant effect on grain yield of wheat, while their interaction were non-significant. It is evident from the results that planting method bed planting 3 rows on beds produced the highest grain yield (5294 kg ha^{-1}), followed by flat planting in rows (5018 kg ha^{-1}) grain yield. The lowest grain yield was recorded by bed planting broadcast (3505 kg ha^{-1}). The grain yield increased with increase in number of irrigations i.e. the plot irrigated twice

produced minimum grain yield (4067 kg ha^{-1}) as compared to that receiving three levels of irrigations. While the plot received five times irrigation produced the maximum grain yield (4936 kg ha^{-1}). Although the interaction between planting methods and irrigation was non-significant, yet the results revealed that increase in grain yield with increase in number of irrigation was lower in bed planting broadcast than other planting methods. The maximum increase in grain yield with irrigation occurred in flat planting 3rd row skip is 1116 (i.e. $I2 = 3931 - I5 = 5047 = 1116$), flat planting in rows is 987 (i.e. $I2 = 4426 - I5 = 5413 = 987$) and bed planting 3-rows on beds is 774 (i.e. $I2 = 4727 - I5 = 5501 = 774$). Similar results are reported that grain yield increased on raised beds because of the increase in grains spike $^{-1}$ and number of spikes [17, 24, 32, 33]. Many researchers studied that Triple-row bed planting produced significantly higher grain yield and the minimum grain yield was obtained from plots sown by Rabi drill on flat [13, 34-37]. The better grain yield of wheat on beds was due to more number of productive tillers, grains spike $^{-1}$ and 1000-grains weight [18]. A number of researchers reported more crop yields by sowing on beds than that of flat [27, 38, 39].

Figure 4. Interactive effect of planting methods and irrigation levels on number of grains spike $^{-1}$.

Figure 5. Interactive effect of year and irrigation levels on number of grains spike⁻¹

Conclusions

Based on the grain yield data, it is evident from the results that planting three rows on beds produced the highest grain yield. Grain yield increased with increase in number of irrigations. The plot irrigated five times produced maximum grain yield as compared to that receiving three and two levels of irrigations. Planting three rows on beds along with five irrigations could increase yield and yield components of spring wheat under semiarid climate.

Authors' contributions

Conceived and designed the experiments: Khair Muhammad Kakar. Performed the experiments: Amanullah. Wrote the paper: Asif Iqbal.

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