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INFLUENCE OF PLANTING BED WIDTH AND IRRIGATION METHODS ON APHID POPULATION INCIDENCE AND CROP WATER PRODUCTIVITY IN WHEAT

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Abstract

Water scarcity and declining irrigation resources have intensified the need for efficient wheat production systems in Pakistan. A field experiment was conducted during the Rabi season at the Water Management Research Farm, Renala Khurd, Okara, to evaluate the influence of different bed widths on wheat productivity and water use efficiency under loamy soil conditions. The experiment was laid out in a Randomized Complete Block Design with four treatments: flat sowing (control), 45 cm bed, 60 cm bed, and 75 cm bed widths, each replicated three times. Growth, yield, irrigation water application, crop water productivity (CWP), and water-saving percentage were recorded. Results showed that bed planting significantly improved wheat performance compared with conventional flat sowing. The 75 cm bed width produced the highest number of tillers (270 m^{-2}), grains per spike (42.89), 1000-grain weight (35.36 g), grain yield (3483 kg ha^{-1}), and crop water productivity (1.427 kg m^{-3}). In contrast, flat sowing resulted in the lowest grain yield (2765 kg ha^{-1}) and CWP (1.047 kg m^{-3}). Total irrigation water applied was highest under flat sowing (264 mm), whereas the 45 cm bed required the least irrigation (221 mm), resulting in the greatest water saving (16.29%). The 60 cm and 75 cm beds saved 10.98% and 7.58% irrigation water, respectively. In case of aphid incidence, comparatively greater incidence was recorded on wheat plants under flat sowing under conventional flood irrigation compared with bed-planted wheat under furrow irrigation. Overall, raised-bed planting enhanced water-use efficiency and wheat productivity under loamy soil conditions. Although the 45 cm bed provided maximum water savings, the 75 cm bed width was the most effective in achieving higher grain

yield and crop water productivity. Therefore, a 75 cm raised bed can be recommended for sustainable wheat production where both yield maximization and efficient water utilization are desired.

INTRODUCTION

Wheat (*Triticum aestivum* L.) holds a supreme position in the world agricultural landscape, serving as the 2nd utmost vital staple food crop next to rice. Its importance mainly marked in developing countries like Pakistan, where it is known as significant nutritional constituent whereas also contributing considerably to the food security, employment generation and economic growth (Ahmad et al., 2026). China and India are the main countries regarding wheat production and consumption in Asia–Pacific region, with an average production of 385.4 million metric tons in 2023 (Mordor Intelligence Research and Advisory, 2024). Developed countries like China lead in crop production though improved agronomic practices, seed technologies and prevalent accessibility of high-quality seed. In Pakistan, wheat production mainly follows outdated and conservation approaches. Traditional crop practices focus on power tillers for land preparation and broadcasting seeds, which upsurges fuel and seed input cost thus increasing the overall production cost of crop (Khatri and Shrestha, 2023). On the other hand, conservation agriculture focuses on timely planting, nominal soil tillage and enhanced placement of fertilizer, and seed, encouraging sustainability and improved productivity (Shrestha *et al.*, 2020).

The rising worth of wheat in Pakistan is obvious, by current research trials elaborating its role as agricultural complement to rice and main nutritional constituent (Ullah *et al.*, 2021). Nevertheless, agricultural land in Pakistan is decreasing owing to industrialization and urbanization (Shah *et al.*, 2023). Water scarcity is turning to be the next limiting factor for wheat production aggravated by the high-water necessities of recently rising area under rice cultivation. Moreover, Worldwide water scarcity, triggered by ever rising populations, poses supplementary challenges to irrigated agriculture, mainly in semi-arid areas where restricted water accessibility limits the crop produce (Biswas *et al.*, 2025). These challenges pinpoint the pressing need for effective water management and the implementation of advanced farming practices to conserve soil moisture, improve the water use efficiency and guarantee sustainable water, and food security (Ali *et al.*, 2025).

In the background of Pakistan, irrigation is vital for wheat production, particularly in the dry season. The restrictions forced by rare water resources signify the need for sustainable management and conservation of water, and soil fertility to avert additional deprivation of these important resources and to improve agricultural output (Jabeen *et al.*, 2022). The deployment of advanced skills preserves soil moisture, together with better irrigation practices, is imperative for attaining water use efficiency. Furthermore, accurate irrigation water management practices are important for enhancing crop water productivity. Conventional approaches of wheat cultivation, like flat sowing and flood irrigation, frequently result in excessive-irrigation, causing glitches such as nutrient leaching, deprived aeration, decreased crop water productivity, lodging of crop and hardening of soil surface (Chen *et al.*, 2018; Tewabe *et al.*, 2020). It is projected that up to 50% of water can be lost by means of surface run-off and deep percolation in few cases, highlighting the inadequacy of traditional irrigation techniques (Rahman *et al.*, 2022).

Quantity of applied irrigation and fertilizers especially nitrogen influences the population sucking pests like aphids. Aphids are minute sucking insect pests which suck the cell sap of crops, resulting sooty mold growth on plant leaves. Irrigation of crops according evapotranspiration is precision water management approach which regulates plant cell sap which ultimately affects the populations of sucking pests. Hence, exploring substitute methods of crop sowing that

meaningfully increase water use efficiency and wheat yield is of supreme worth.

Worldwide, the adoption of raised bed (RB) planting has been known as an operative approach for improving crop water productivity (Ismail *et al.*, 2021). Originally adopted by over 90% of farmers in Mexico's Yaqui Valley, RB agriculture provides a planned reaction to water management challenges, turning to be more effective in using irrigation water compared with conventional border irrigation and decreasing manpower through furrows rather than conventional flood irrigation (Tewabe *et al.*, 2020). The adoption of RB farming, an innovative method of conservation agriculture, offers a feasible tactic for improving the resource efficiency and sustainability of irrigated wheat-based cropping systems. Adoption of RB skill in Bangladesh, has exemplified its rising reception and potential to meaningfully advantage the farming sector (Nazu *et al.*, 2022).

RB furrow irrigation, categorized by the separation of fields into narrow RBs divided by furrows, characterizes a noteworthy development in agricultural water management. This system not only helps in water flow but also considerably progresses soil moisture delivery, thus bring into line more meticulously with the crops' water requirements (Munmun *et al.*, 2024). In this technique, the water in the furrows intermingles with an inadequate surface area, remarkably decreasing glitches linked with soil crusting, evaporation losses and puddling, frequently come across in conventional flat irrigation systems (Pan *et al.*, 2019). Widespread research has emphasized the critical part of bed dimensions in distressing numerous agricultural parameters, like soil water situations and crop development, signifying that optimizing bed width is essential for enhancing soil water content, grain yield, and water use efficiency (Du *et al.*, 2023). Furthermore, it has been observed that suboptimal furrow bed sizes can remarkably decrease efficiency of irrigation application (Tewabe *et al.*, 2020). Recognizing the best bed width is therefore vital, considering aspects like specific water needs of the crop and soil texture, to balance the improved water accessibility against potential waterlogging dangers (Munmun *et al.*, 2024).

In spite of the established benefits of RB-based irrigation in increasing crop productivity water use efficiency in different cropping systems, the maximization of furrow bed dimensions mainly RB width remains ineffectively studied for irrigated wheat farming. Finding the best suitable bed width is of prime importance, as it mainly affects the distribution soil moisture, root development, and finally the crop yield. In Bangladesh and rest regions of Asia, conventional RB widths for wheat cultivation in agronomic research trials and on-farm applications mainly range from 50 to70 cm. Narrower beds (25-30 cm) are practiced in water-shortage zones to help high-density planting, whereas wider beds (60-75 cm) are implemented to enhance efficiency of machinery and decrease labor cost (Munmun *et al.*, 2024). Nevertheless, standardized bed widths in changing agroecological circumstances remain inadequately explored. For example, in China bed width of 45-65 cm is being adopted by farmers in wheat-rice systems, striking a balance between yield and water conservation (Du *et al.*, 2022). To bridge this research gap, the present research trial was conducted using three RB widths; 45 cm (narrow), 60 cm (intermediate) and 75 cm (wide) showing field extremes and a middle ground width steady with new approvals for semi-arid regions (Dass and Pandy, 2024). These widths were designated to address a main information gap in Pakistan, where farmers frequently use random bed sizes owing to a deficiency of indigenous agronomic research trials. RB farming is extensively documented for improving drainage, decreasing soil compaction and increasing aeration, experimental indication on how precise bed widths impacts water use efficiency and wheat yield remains restricted. By knowing the optimum bed width, the aim is to assist the farmers in optimizing irrigation practices, increasing wheat production efficiency, and addressing challenges in irrigated agriculture. This research trial is mainly important for Pakistan, where sustainable water management and improved crop productivity are vital for guaranteeing food

security amid mounting weather and resource limitations.

Materials and Methods

Experimental site

The present research trials were conducted at Water Management Research Farm, Renala Khurd, Okara, during Rabi season, having longitude and latitude of 30.8782° N, 73.5954° E, correspondingly and is 67 m above sea level.

Experimental setup

The research trial was conducted at Water Management Research Farm, Renala Khurd, Okara, during the Kahrif Season, 2025-26. Treatments were arranged under Randomized Complete Block Design with nine plots, each measuring 10 m × 66 m. This design was designated to lessen spatial inconsistency and guarantee equivalent representation of treatments across the field. The plot size was designed on the basis of accessible land resources at the research trial location whereas sustaining a buffer zone of 1 m between plots to avert cross-treatment interference. Moreover, the factorial structure comparing three different bed widths (45 cm, 60 cm and 75 cm) against one control of each bed size was precisely selected to address the core research question of optimizing bed width for wheat cultivation. Each bed size was replicated thrice (Gomez and Gomez, 1984). The 45 cm width signified a high-density configuration to optimize bed moistening, whereas the 75 cm width illustrated wider beds used in mechanized systems to decrease labor and furrow numbers (Tewabe et al., 2020).

Table 1 Description of treatments

Treatment	Width (cm)
T_0	Farmer practice of wheat sowing (flat sowing)
T_1	45 cm wide bed
T_2	60 cm wide bed
T_3	75 cm wide bed

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Field works and data recording

Earlier to starting the research trial, the field underwent complete preparation; plowing, harrowing, planking and laser land levelling to ensure optimal soil conditions. Recommended doses of fertilizers were applied: urea (N) at a rate of 200 kg/ha, diammonium phosphate (DAP) at 125 kg/ha and sulphate of potash (SOP) at 60 kg/ha. Wheat variety, Akbar-2019 was sown through broadcast method and beds of 45, 60 and 75 cm were raised thereafter to make sowing technique farmer friendly. Net plot size was 660 m^2. Irrigation management was meticulously planned and executed based on soil moisture content and critical growth stages of the crop, including crown root initiation, booting, flowering, and grain filling stages. Initial irrigation was applied to achieve up to 80% and subsequently 60% of field capacity to support germination, with soil moisture content monitored using a soil moisture profiler (Delta-T Device Co., UK). Irrigation was done through cut-throat flume 8' × 3' size. Finally, the fully matured crop was harvested and processed in accordance with appropriate operations.

Aphid population incidence

Aphids population was counted from randomly selected wheat plants from each of the planting bed geometry and average computed.

Crop water productivity

It was computed by dividing the grains yield (kg m^{-3}) by total quantity of water;

$$\text{Crop Water Productivity (Kg/m}^3) = \frac{\text{Grains Yield (Kg/ha)}}{\text{Amount of water applied (m}^3\text{/ha)}}$$

Statistical analyses

Data of related to growth and yield parameters of wheat were precisely noted down for statistical analysis. Statistix software was used for calculation of analysis of variance (ANOVA) and treatments average values were compared through Fisher's least significant difference (LSD) test at a 5% significance level.

Results

The results presented in the table indicate that bed size had a noticeable effect on the growth and yield-related traits of wheat (Table 2). Plant height increased progressively with increasing bed width, where the highest plant height among bed planting treatments was recorded in the 75 cm bed size (90.34 cm), followed by the 60 cm (89.34 cm) and 45 cm beds (87.45 cm). However, the control treatment (flat sowing) produced the tallest plants (92.10 cm).

Table 2 Growth parameters of wheat sown on planting beds of different sizes

Bed size (cm)	Plant height (cm)	Tillers m^{-2}	Grains $spike^{-1}$	1000-grains weight (g)
45	87.45	256	39.26	34.10
60	89.34	261	40.65	34.89
75	90.34	270	42.89	35.36
Control	92.10	275	36.14	32.90
LSD (0.05)	0.1034	0.528	0.4190	0.006

Control=Flat sowing of wheat

The average irrigation depth decreased slightly from the first to the third irrigation across all treatments (Table 3). Farmer practice consistently received the highest irrigation depth (94, 87, and 83 mm), whereas the 45 cm bed received the lowest depth (75, 74, and 72 mm). The 60 cm and 75 cm beds showed intermediate values, with the 75 cm bed requiring slightly more water than the 45 cm and 60 cm beds. Overall, bed planting systems reduced irrigation water application compared with conventional farmer practice, and the 45 cm bed demonstrated the greatest water-saving potential.

Table 3 Average irrigation depth under dissimilar widths of planting beds

Irrigations	Average irrigation depth applied (mm) per bed size			
	Bed (45 cm)	Bed (60 cm)	Bed (75 cm)	Farmer practice
1st	75	81	86	94
2nd	74	79	80	87
3rd	72	75	78	83
Total	221	235	244	264

Control=farmer practice of flat sowing, Rouni=100 mm

The aphid population increased steadily with crop growth in all treatments from February to mid-March (Fig.1). Among the treatments, flat sowing consistently recorded the highest aphid infestation, with the population rising from approximately 1.6 aphids at the first observation to more than 6.0 aphids at the final observation date. The 60 cm planting bed exhibited the second-highest aphid population, increasing from about 1.2 to 5.3 aphids during the study period.The 45 cm planting bed showed moderate aphid infestation, with populations increasing from approximately 0.6 aphids at the initial stage to about 4.1 aphids by the final observation. In contrast, the 75 cm planting bed maintained the lowest aphid population throughout the season, with values ranging from about 0.4 aphids at the

first observation to only 2.9 aphids at the last sampling date.

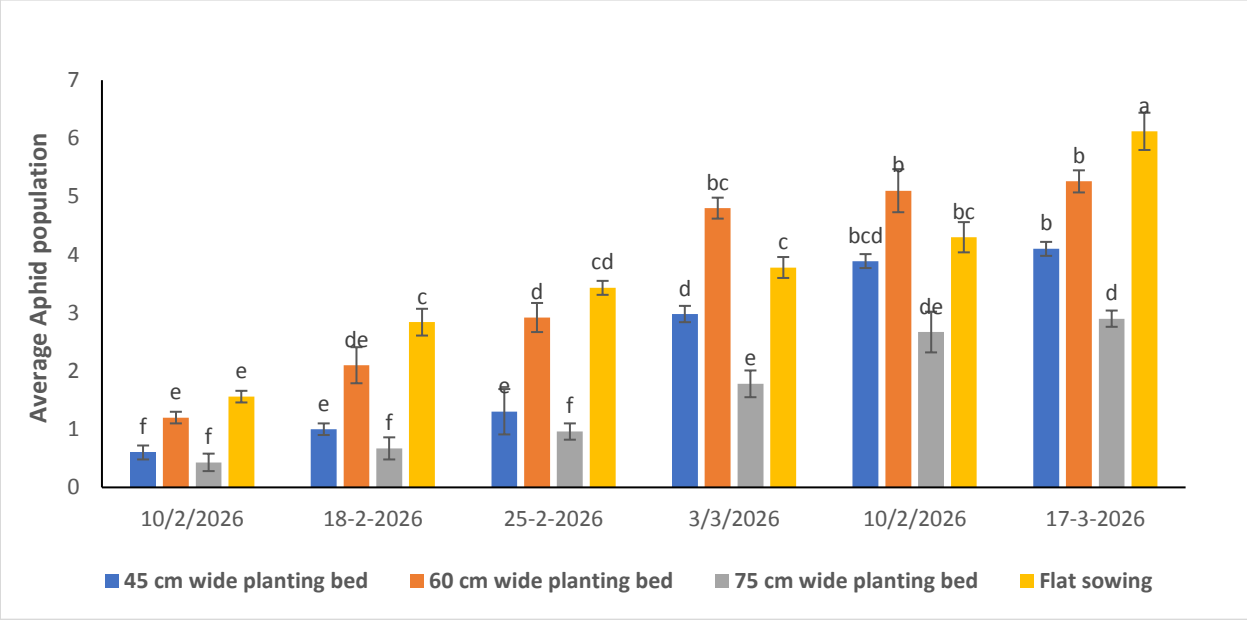


Table 4 Compassion of average irrigation depth, crop water productivity and water saving values under dissimilar widths of planting beds

The results showed that bed planting reduced irrigation water use and improved grain yield and crop water productivity (CWP) compared with conventional flat sowing (Table 4). Flat sowing required the highest irrigation water (264 mm), whereas the 45 cm, 60 cm, and 75 cm beds reduced water application by 16.29%, 10.98%, and 7.58%, respectively. The highest grain yield (3483 kg ha^{-1}) and CWP (1.427 kg m^{-3}) were achieved with the 75 cm bed, followed by the 60 cm and 45 cm beds, while flat sowing produced the lowest yield (2765 kg ha^{-1}) and CWP (1.047 kg m^{-3}). Overall, bed planting proved superior to flat sowing by enhancing water-use efficiency and crop productivity, with the 75 cm bed performing best for yield and CWP and the 45 cm bed providing the greatest water savings.

Sowing practice	Total irrigation applied (mm)	Yield (kg/ha)	CWP	Water saving (%) over control plot
45 cm wide bed	221c	2890b	1.307	16.29
60 cm wide bed	235b	3195ab	1.359	10.98
75 cm wide bed	244b	3483a	1.427	7.58
Flat sowing	264a	2765b	1.047	-

Discussion

Wheat is an important cereal crop worldwide. Water availability for agricultural crops is decreasing due to less efficient irrigation methods. The present research work on cultivation of wheat on beds and furrow irrigation showed that there were relatively grains per spike, greater number of tillers m^{-2} and 1000-grains weight values in case of wheat cultivated on beds under furrow irrigation compared with flat sowing under traditional

method of flood irrigation. Comparatively greater grains yield and less quantity of irrigation was recorded in case of wheat on beds compared with flat sowing practice. Maximum water saving was recorded in case of 45 cm wide bed compared with other bed width.

Though plant height did not significantly vary across treatments, maximum plant height was measured in case of wheat plants under farmer practice of irrigation. The results were in accordance with Hashimi *et al.* (2021), who noted relatively greater plant height in case of flat sowing compared with wheat plants under bed sowing with furrow irrigation. The raised bed technique in the present study improved the growth characteristics of wheat. This enhancement in plant growth is supported by Soomro *et al.* (2017), who observed enhancements in wheat growth parameters by different bed planting approaches. Comparatively a smaller number of tillers and grains per spike were recorded in experimental plots under traditional flooding. The results were in line with Kaur *et al.* (2020) who specified that continuous flooding technique could results in soil waterlogging and compaction, possibly affecting plant growth harmfully. There were also comparatively higher grain yield and weight of wheat plant under raised bed technique than the flat sowing practice. The similar trend was also recorded by Ismail *et al.* (2021) and Rady *et al.* (2021) also increase in grains yield and weight values on raised bed planting. The present research work underscores the benefits of raised bed cultivation like increased root spread, soil moisture conservation and aeration for growth of spike and grains weight. This is reinforced by the outcomes of Dass *et al.* (2024), who highlights the significance of bed width in agricultural efficiency. The outcomes of the current research work specifies that the raised bed method, mainly with a 45 cm bed width, could serve as an effective substitute to flat sowing practice owing to its capability to improve lateral water distribution and moisture conservation. The outcomes in accordance with Du *et al.* (2023) who described that raised bed method of planting meaningfully rises grain yield over farmer practice of flat sowing. Likewise, Razaq *et al.* (2019) also noted rise in grains yield in research plot of wheat under raised bed technique over flat sowing. Results of plant height in the present study were somewhat superior in case of flat sowing than the bed sowing technique. Traditional flooding supply more water which boosts up the vegetative growth of plants. The results were supported by Jha *et al.* (2019), who recorded that abundant water supply can upsurge vegetative biomass at the expense of grain yield. The results were verified by research outcomes of Fischer *et al.* (2019), who recorded enhancements in crop yield with improved irrigation management and plant spacing. Results of comparatively lower grains yield in farmer practice of flat sowing as was observed in the present study was may be due to comparatively less planting space compared with bed planting technique. The similar effect was also observed by Jaenisch *et al.* (2022). This steadiness across treatments underlines the consistency of raised methods as a potential substitute to traditional flat sowing methods, improving the effectiveness of conversion of biomass into grain.

Water use efficiencies and irrigation water-saving

The outcomes of the present research work show that raised bed technique showed relatively greater values of crop water productivity compared with flat sowing practice. The outcomes that width of bed affects use of irrigation water and crop water productivity is imperative, as beds with furrow arrangement comparatively require less quantity of water compared with flat sowing. This raised bed technique not merely improves crop water productivity but also conserve water in agriculture. These results were supported by research findings of Razaq *et al.* (2019), who recorded enhancement in grains yield and crop water productivity by raised bed method compared with flat sowing practice. In the present research, there was 7-16% water saving recorded through raised bed technique. Likewise, Hossain *et al.* (2019), who described a 15.52% water savings with RB methods over traditional practice of flat sowing. Similarly, Ismail *et al.* (2021) also established that adopting raised bed practice could result in water

savings of 15-21% over the traditional flat sowing practice. This collective indication underlines the key role of raised bed practices in improving water use efficiency and soil moisture conservation in agricultural systems, signifying a move to more supportable irrigation approaches is both viable and useful.

Conclusions

The results showed that bed planting reduced irrigation water use and improved grain yield and crop water productivity (CWP) compared with conventional flat sowing. Flat sowing required the highest irrigation water (264 mm), whereas the 45 cm, 60 cm, and 75 cm beds reduced water application by 16.29%, 10.98%, and 7.58%, respectively. The highest grain yield (3483 kg ha^{-1}) and CWP (1.427 kg m^{-3}) were achieved with the 75 cm bed, followed by the 60 cm and 45 cm beds, while flat sowing produced the lowest yield (2765 kg ha^{-1}) and CWP (1.047 kg m^{-3}). Overall, bed planting proved superior to flat sowing by enhancing water-use efficiency and crop productivity, with the 75 cm bed performing best for yield and CWP and the 45 cm bed providing the greatest water savings.

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