Research Article

Enhancing Wheat Yield through Optimal Sowing Techniques in Arid Region of Pakistan

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Abstract | Wheat (*Triticum aestivum* L.), a staple food crop of Pakistan, plays a crucial role in ensuring food security and economic stability. To optimize wheat yield and productivity, sowing methods may greatly influence crop performance. This study aimed to assess the effects of different sowing methods on spring wheat yield. The experiment was carried out in 2020-21 and repeated in 2021-22 under Randomized Complete Block Design (RCBD) with three replications focusing on five sowing methods (i.e. the conventional broadcasting, bed sowing (75 cm distance), augmented furrow (60 cm distance), modified drill (15.5 cm distance) and drill sowing (22.5 cm distance). Results revealed that sowing methods significantly influenced wheat production. Among treatments, augmented furrow expressed consistently the higher grain yield (42.46%) compared to conventional broadcast method, which was due to its ability for plants to maintain optimum density per unit area, reduced intraspecific competition, and enhanced grain formation, leading to higher grain yield (5562.38 kg ha^{-1} in 2020-21 and 5220.22 kg ha^{-1} in 2021-22). Adapting an appropriate sowing method is crucial to maximize wheat production which has been proved in the augmented furrow method over a broadcast and/or the usual drill sowing methods. The relatively better performance of augmented makes it the preferred choice for enhancing per unit area productivity. Findings of this study can hold a significant implication on curtailing wheat area expansion and ensuring future food security.

Received | August 28, 2023; **Accepted** | February 01, 2024; **Published** | June 22, 2024
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Citation | Zawar, S., M.W. Yonas, M.M. Akbar and A. Ahmad. 2024. Enhancing wheat yield through optimal sowing techniques in Arid region of Pakistan. *Sarhad Journal of Agriculture,* 40(2): 672-679.
DOI | https://dx.doi.org/10.17582/journal.sja/2024/40.2.672.679
Keywords | Arid agriculture, Productivity, Sowing method, *Triticum aestivum*

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Introduction

Wheat (*Triticum aestivum*) holds a prominent position being one of the most vital staple food crop, catering to the dietary needs of populations worldwide (Peña-Bautista *et al*., 2017; Taglieri *et al*., 2021). Wheat stands out as a nutritionally balanced and indispensable food source human health (Singh *et al*., 2019). Distinguished from other cereal crops, wheat offers a diverse array of nutrients in various food forms, establishing itself as a cornerstone of global nutrition (Soomro *et al*., 2009). Comprising a significant portion, accounting for 28% world edible crop biomass, and with the potential to contribute up to 60% of daily caloric intake in impoverished regions, wheat plays a pivotal role in effectively addressing food security challenges (Khatri *et al*., 2019).

In Pakistan, it plays a significantly role in agricultural sector, contributing 8.7% of value addition and 1.7% of the GDP (Asif *et al*., 2019). Cultivated over 8 million ha with an average yield of 2800 kg ha^{-1}, wheat holds a significant role in the economic and agricultural sectors in Pakistan (Tanveer *et al*., 2003). However, achieving lower wheat grain yields than the potential may be attributed to factors such as the unavailability of recommended seed varieties, planting delays, inappropriate methods, fertilizer imbalances, and poor water management (Khan *et al*., 2007). The selection of an appropriate sowing method is crucial for ensuring seed placement and successful crop emergence (Noor *et al*., 2020; Yonas *et al*., 2020; 2023). The sowing methods significantly impact the availability of water, nitrogen, phosphorus, and soil compaction (Trodson *et al*., 1989), as well as the distribution and absorption of sunlight crucial for photosynthesis, thereby influencing crop growth (Lal *et al*., 1991). Mishra and Tiwari (1999) found that the broadcast sowing method results in lower root weight compared to non-conventional methods and conventional sowing methods exhibit higher weed density, thereby affecting overall crop growth and grain yield. Previous studies have shown that various sowing methods elicit diverse responses, which can vary under different experimental conditions. Notably, Hussain *et al*. (2018) demonstrated that sowing wheat in furrows resulted in the highest 1000-grain weight, straw yield, and grain yield.

Sowing techniques play a vital role in wheat crop germination, influencing the conservation of residual soil moisture in the root zone, and aiding wheat plants in absorbing sufficient fertilizers and water (Twizerimana *et al*., 2020). Proper sowing methods, particularly precise planting, have demonstrated their ability to optimize resource availability, encompassing sunlight capture, moisture retention, and nutrient availability. Consequently, this promotes robust root system development right from the early stages of crop growth, establishing the groundwork for higher yields and improved crop performance (Twizerimana *et al*., 2020). The objective of this study was to pinpoint the most profitable sowing technique for Pakistan with the aim of increasing wheat production.

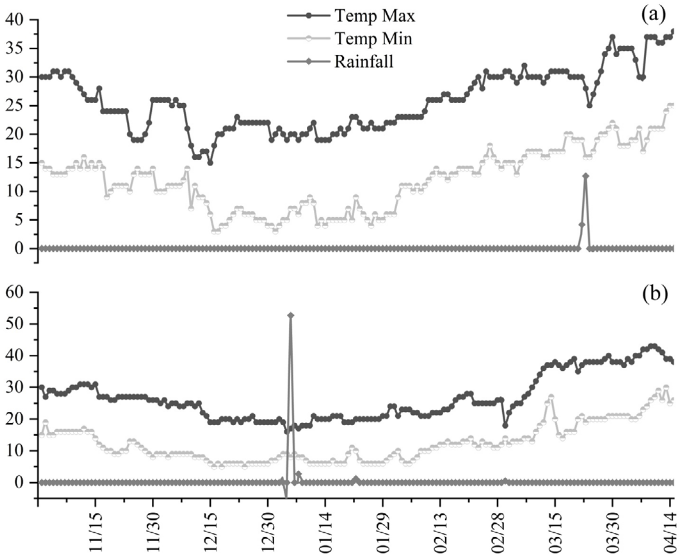

Figure 1: *Climatic conditions for wheat growing seasons 2020-2021 and 2021-2022. (a) depicts the weather conditions during 2020-2021, while (b) illustrates the weather conditions during 2021-2022.*

Materials and Methods

Field experiment was conducted at Muhammad Nawaz Shareef University of Agriculture in Multan, Pakistan. The field is situated in an arid region within Multan District at 30 N latitude and 71 E longitudes, with an elevation of 122 m above sea level. Multan experiences a hot and dry climate, characterized by an average annual rainfall of 175 mm. The temperature ranges from a maximum of 49°C during summer to a minimum of 1°C in winter (Majid *et al*., 2020). Weather data for the crop season, encompassing maximum and minimum temperatures, as well as rainfall, were collected from the Agro-meteorological Cell, Department of Agronomy, Muhammad Nawaz Shareef University of Agriculture in Multan (Figure 1A, B). The soil type at the site is identified as saline Indus plain Haplic Yermosol (FAO-UNESCO, 1977; Yonas *et al*., 2023). The physico-chemical analysis is shown in Table 2. The primary objective of this study was to ascertain the most effective and recommended method for achieving higher wheat yield. The experiment employed a single-factor design within a Randomized Complete Block Design (RCBD) with three replications and five treatments. Each plot measured 20 m x 5 m. Sowing, using. AKBAR-19 cultivar, occurred in mid-November for both years. The land was meticulously prepared through ploughing and planking. In broadcast sowing method, wheat seeds were manually scattered in the plot, while other agronomic practices remain consistent with other treatments (Figure 2). For bed method, the soil was thoroughly prepared, and bed were established using bed planter after manually broadcasting seeds. The distance between beds was maintained at 75 cm. In the augmented furrow method, seeds were manually broadcasted both from north to south and east to west. Furrows were then formed using a potato ridger with a spacing 60 cm. For the rabi drill sowing method, lines were made 22.5 cm apart on well-prepared soil. In the modified drill method, the line spacing was reduced to 15.5 cm compared to the rabi drill method. The seed rate utilized in all treatments was 120 kg ha^{-1}, and fertilizers were applied at the recommended rate of 120-90-60 N-P-K kg ha^{-1}, with phosphorous and potash used as basal doses. Urea was applied in three splits: the 1st dose of 50 kg ha^{-1} as basal dose, the 2nd 40 kg ha^{-1} at tillering stage and the 3rd dose of 30 kg ha^{-1} at booting stage. Irrigation was scheduled based on the crop's water requirements and the gaps in rainfall. In this study three irrigations were applied at critical stages (1st irrigation was applied at tillering stage, 25 DAS; 2nd at booting stage, 58 DAS; and 3rd irrigation was applied at milking stage, 82 DAS) excluding rain outbreak and the irrigation for seedbed preparation. Harvesting of the crop occurred in mid-April during both growing seasons. Data were collected from all treated plots by using a quadrant of 1m^{-2}. Emergence was recorded by counting all individual seedlings from each plot, utilizing a randomly selected 1 m^2 quadrant, at 11 and 20 DAS. The mean value was then calculated by following the method by Giri and Schillinger (2003). Grain yield and parameters related to yield components such as 1000 grain weight, number of grain spike^{-1}, spike length, number of spikelet spike^{-1}and plant length was recorded at the harvesting stage using quadrant method. A 1 meter^2 quadrant was randomly employed in each plot, with three repetitions to determine the samples from each plot. The samples were weighed, threshed, and the weights of the grains were recorded for each replicate. subsequently, the mean value will be calculated by averaging the replicated data. At the harvesting stage, data on the plant height and spike length were recorded by randomly, selecting a total of six plants each plot. Additionally, 1000 grains were collected from each plot, and their weights were documented. The collected data were analyzed by using the software Statistix 10, employing analysis of variance, and mean separation were performed using Tukey's honestly significant difference (HSD) test at a 0.05% probability level. A PCA biplot was generated by using Origin Lab, 2021.

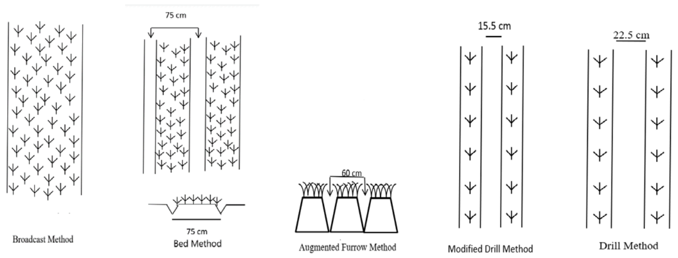

Figure 2: *Sowing methods plan of study during 2020-21 and 2021-22.*

Results and Discussion

The employed sowing methods had a notable impact on wheat emergence, as evidenced by the data presented in Table 1. The augmented furrow method resulted in the highest number of emergence wheat plants, closely followed by the beds method. In contrast, poor wheat emergence was observed when employing the broadcasting and rabi drill methods. The analyzed data revealed significant differences among the various sowing methods in terms of spike length and the number of spikelets spike^{-1} during both rabi growing seasons. In the 2020-21 season, the augmented furrow method produced highest spike length of 11.67 cm, while broadcast method demonstrates the lowest spike length of 8.34 cm. The bed method achieved second highest spike length followed by augmented furrow, with a measurement of at 9.167 cm for both growing seasons. In terms of the number of spikelets spike^{-1}, the augmented furrow method consistently demonstrated a highest count, with 16 spikelets during both seasons. In contrast, the broadcast method exhibited lowest number of spikelets in consective years; however, in 2021-2022 season, it demonstrated 9.00 spikelets spike^{-1}. The augmented furrow method is followed by the bed and modified drill method. The analysis highlighted the substantial impact of sowing method on both spike length and spikelets spike^{-1}. The augmented furrow method demonstrated favorable conditions in terms of spike length and spikelets spike^{-1}. In contrast, the broadcast method had less favorable conditions for both parameters. While the modified drill method and drill method exhibited potential for improved spike length and spikelets spike^{-1}, but their performance did not match the effectiveness of the augmented furrow method. The study demonstrated disparities plant height under different sowing methods during

Table 1: *Effect of sowing methods on emergence m^{-2}, yield and yield contributing characters of wheat crop during growing season 2020-2022.*

Treatment	Emergence m^{-2}		Spike Length cm		Tiller Length cm		Spikelet's Spike^{-1}		Grains Spike^{-1}		Productive Tillers m^{-2}		1000 Grain Weight g		Grain Yield Kg ha^{-1}	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Broadcast method	129^{d}	127^{d}	8.83^{b}	8^{b}	80.34^{c}	81^{b}	10.33^{b}	9.34^{b}	37^{b}	38.66^{b}	193.66^{d}	190.66^{e}	30.67^{c}	32.34^{b}	2314.25^{c}	2261.78^{c}
Bed method	145^{b}	156^{b}	9.16^{b}	9.17^{b}	86.67^{bc}	84.67^{b}	12^{ab}	12^{ab}	38.667^{b}	42.33^{ab}	217.66^{b}	234.33^{b}	35.67^{b}	34.00^{b}	2862.58^{b}	3438.38^{b}
Augmented furrow method	186^{a}	182^{a}	11.16^{a}	11^{a}	100.3^{a}	97.67^{a}	16^{a}	16^{a}	49^{a}	47^{a}	279^{a}	273^{a}	40.74^{a}	40.74^{a}	5562.38^{a}	5220.32^{a}
Modified drill method	139^{bc}	143^{c}	9.83^{b}	9^{b}	87.67^{b}	83.67^{b}	12.67^{ab}	10.67^{b}	35.333^{b}	40.66^{b}	209^{bc}	214.33^{c}	36.17^{b}	34.67^{b}	2556.01^{bc}	3151.23^{b}
Drill method	135^{cd}	139^{c}	9.83b	8.67^{b}	82.67^{bc}	83^{b}	11.67^{b}	11^{b}	38.333^{b}	39.66^{b}	203^{cd}	207.33^{d}	35.87^{b}	35.34^{b}	2751.6^{b}	3023.65^{b}
HSD value	6.7	4.2	1.25	1.54	6.39	10.83	4.16	4.42	5.5	5.4	9.9	6.8	3.27	4.08	403	484

the 2020-21 and 2021-22 growing seasons. The augmented furrow method exhibited the highest plant heights, measuring 100.33 cm and 97.67 cm, respectively. In contrast, the broadcast method resulted in the lowest plant height, with measurements of 81.00 cm and 80.33 cm during both years. The next highest plant height was observed with the modified drill method, measuring 87.67 cm and 83.64 cm. Following closely were the results of the bed sowing method, showing plant height of 86.6 cm and 84.667 cm respectively. These findings indicate that different sowing methods significantly influenced plant height, with the augmented furrow method producing the most positive outcomes. Among the various sowing methods studied, the augmented furrow method resulted in the highest grain spike^{-1}, with 49 and 47 grains obtained during both seasons. In contrast, the broadcast method showed the lowest counts, with 37.00 and 38.67 grains spike^{-1}for the both growing seasons. The bed method yielded the next highest results, with 38.67 and 42.34 grains spike^{-1}, followed by the rabi drill method, which produced 38.34 and 39.67 grains spike^{-1} in both growing years. This underscores the significant influence of different sowing methods on the number of grains spike^{-1}. Throughout both growing seasons, the augmented furrow method exhibited the highest productivity in terms of tillers, recording measurements of 279.00 and 273.00 m^{-2}. In contrast, alternative methods displayed lower productive tiller counts: 193.66 and 190.66 m^{-2} for broadcast, 217.66 and 234.33 m^{-2} for the bed method, 209.00 and 214.33 m^{-2} for the modified drill method, and 203.00 and 207.33 m^{-2} for the rabi drill method. The study revealed significant variations in the 1000-grain weight across different sowing methods. The augmented furrow method achieved the highest 1000-grain weight of 40.733 g, indicating its superiority in this aspect. Conversely, the broadcast method recorded lowest grain weights of 30.677 g and 32.333 g. The modified drill method showed the next highest grain weights of 36.167 g and 34.667 g, closely followed by the drill method with weights of 35.867 g and 35.333 g in both the growing seasons of 2020 and 2021. The presented yield data indicates a significant difference among all treatments (Table 1). The augmented furrow sowing method resulted in the highest grain yield, with 5562.38 kg ha^{-1} in 2020-21 and 5220.32 kg ha^{-1} in 2021-22. In contrast, the broadcast sowing method exhibited the lowest grain yield, recording 2314.25 kg ha^{-1} in 2020-21 and 2261.78 kg ha^{-1} in 2021-22. Among the other sowing methods, the bed, modified drill, and rabi drill treatments performed well, producing 2862.58 kg ha^{-1}, 2556.01 kg ha^{-1}, and 2751.6 kg ha^{-1}, respectively, in 2020-21. In 2021-22, the modified drill treatment produced 3151.23 kg ha^{-1}, which was statistically similar to the yields obtained from the bed 3438.38 kg ha^{-1} and rabi drill 3023.65 kg ha^{-1} sowing methods. In this study, Principal Component Analysis (PCA) was applied to the dataset, resulting in the extraction of two components that jointly accounted for 97.27% of the total variation among treatments over the span of the growing years from 2020 to 2022 (Figure 3). Throughout the study duration, significant disparities in how wheat emergence, yield, and yield components responded to various sowing methods. Notably, the sowing methods were dispersed across different quadrants, providing compelling evidence of substantial variations among the sowing methods and their association with the different parameters. Among all the sowing methods, the augmented furrow method clearly demonstrated its superiority over the others in improving wheat crop productivity throughout the study period. Remarkably, emergence

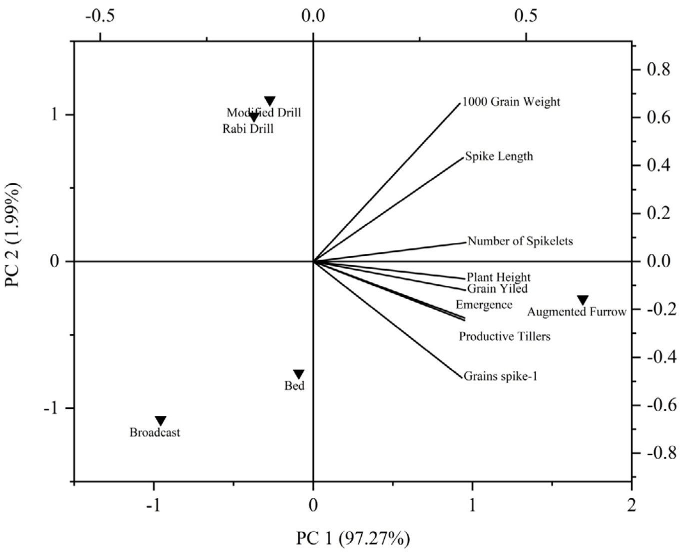

Figure 3: *Principal Component Analysis (PCA) biplot for various sowing methods, emergence, and yield.*

Table 2: *Physio-chemical analysis of study site during growing season 2020-2022.*

Soil parameters	2020-21	2021-22
EC ($mScm^{-1}$)	1.49	1.46
Soil pH	7.78	7.8
Organic matter (%)	0.63	0.62
Avail. N (%)	0.05	0.04
Avail. P (ppm)	8.3	8
Avail. K (ppm)	245	225

and all yield parameters exhibited a strong and positive association with the augmented furrow method. Conversely, broadcasting, bed sowing, modified drill, and rabi drill methods displayed negative associations with emergence, yield components, and wheat yield.

Among the various methods that were evaluated, the augmented furrow method consistently demonstrated superior performance across several key aspects. Notably, there was significant variation in seedling emergence m^{-2} within the different sowing methods. The augmented furrow method achieved the highest emergence m^{-2}, possibly attributed to its optimal and uniform seed placement at an appropriate depth. In contrast, broadcasting may have resulted in seed placement on the soil surface, rendering them susceptible to damage from adverse weather conditions. A similar observation of poor wheat emergence with broadcasting, compared to the augmented furrow method, was also reported by Munir *et al*. (2021). The plant height of the wheat crop also varied significantly among the different sowing methods, attributed to the optimum plant population achieved through proper planting geometry. The planting geometry positively influenced plant height by providing adequate space for plant growth. The augmented furrow method exhibited the highest plant height compared to the other methods. This can be attributed to the fact that the augmented furrow method ensured not only uniform seed placement and seeding depth but also sufficient moisture availability and space for capturing light and aeration. As a result, the augmented furrow method led to better germination, resulting in a stronger crop stand and ultimately higher crop productivity (Tanveer *et al*., 2003). An appropriate sowing method is essential for enabling plants to utilize available nutrients, light, and space effectively, leading to enhanced photosynthesis and synthesis of more photosynthates. Additionally, properly spaced plants avoid root competition for moisture and nutrients, which positively affects crop growth and yield. Studies by Tareen *et al*. (1988), Khan *et al*. (2000), and Riaz *et al*. (2022) have all shown that better grain yield is attributed to better plant population and uniform geometry in the field. The data presented in Table 1, Figure 2 reveals that the augmented furrow method resulted in higher plant height, spike length, spikelets $spike^{-1}$, grains $spike^{-1}$, and 1000-grain weight compared to other methods that resulted in higher grain yield at maturity. This can be attributed to the increased surface area

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available in the augmented furrow method, allowing for easier access to water and nutrients for the plants. Consequently, the yield contributing factors lead to higher crop yield, which may be a result of their strong correlation with grain yield (Iqbal *et al*., 2022). On the other hand, sowing wheat crop by using broadcasting, bed, and modified drill, and rabi drill methods resulted in lower plant population, plant height, and all other yield-contributing factors, leading to decreased crop yield. This could be due to the unavailability of proper space, water, and nutrients for the plants in these methods. Beds and ridges tend to dry out early, and nutrients may leach down from the root zone of wheat. Moreover, wheat, being a fibrous rooted crop, may struggle to absorb nutrients and moisture in these methods. Studies by Tanveer *et al*. (2003) have shown that wheat sown on raised beds may face emergence problems, and water stress during the grain-filling stage can lead to lower 1000-grain weight and grain yield. The choice of optimum sowing method plays a significant role to achieve the genetic potential of the cultivar. The augmented furrow method proved to be superior in providing the necessary conditions for optimal plant growth, resulting in good crop stand and higher wheat yield and yield components. Proper seed placement, spacing, and soil contact, as well as the availability of water and nutrients, are crucial factors that can be effectively addressed by selecting appropriate sowing methods for wheat cultivation.

Conclusions and Recommendations

The results consistently indicated that the augmented furrow method outperformed other sowing methods in various crucial growth and yield parameters, including plant height, spike length, spikelets spike^{-1}, grains spike^{-1}, and 1000-grain weight. This method facilitated optimal planting geometry by ensuring uniform seed placement, appropriate spacing, and sufficient moisture availability. These factors had a positive influence on crop growth and factors contributing to yield. The findings underscore the critical importance of selecting the appropriate sowing method for wheat cultivation to enhance crop productivity and overall yield. Adopting the augmented furrow method has the potential to significantly improve wheat production, thereby contributing to both food security and economic growth. Addressing challenges related to sowing practices and resource management within the agricultural sector can lead to higher yields and improved crop performance.

Acknowledgments

The authors would like to express their gratitude to the Director of Farms at MNS University of Agriculture Multan, Pakistan, for generously providing the agricultural land necessary for conducting this experiment, along with all the associated agricultural inputs and resources.

Novelty Statement

The augmented furrow method has significant potential to enhance wheat yield components, leadind to improvement in both food security and economic growth.

Author's Contribution

Shoaib Zawar: Conducted field trial, data collection and preparing first draft.
Muhammad Waqas Yonas: Helped data compilation, data analysis, and final draft preparation.
Muhammad Mujahid Akbar and Abeer Ahmad: Help in data curation, software, and first draft preparation.

Conflict of interest
The authors have declared no conflict of interest.

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