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## Response of Wheat to Different Seed and NPK Fertilizer Rates under the Agro-Climatic Conditions of a Cotton-Wheat Cropping System, Punjab, Pakistan

Ishtiaq Hassan<sup>1</sup> , Muhammad Tariq<sup>1</sup>, Liaqat Ali<sup>2</sup>, Muhammad Shahid<sup>2</sup>, Muhammad Shahbaz<sup>3</sup>, Sidra Batool<sup>4</sup>, Amna Batool<sup>5</sup>, Muhammad Shafqat<sup>6</sup>, Memoona Shehzadi<sup>6</sup>, Muhammad Saleem Kashif<sup>8</sup>, Muhammad Shaiban<sup>7</sup> and Ghulam Fareed<sup>3</sup>

### Abstract

Wheat, being a staple food crop in Pakistan—especially under the cotton and wheat cropping system in Punjab—faces persistent yield stagnation due to inappropriate seed rates and imbalanced nutrient management. This study aimed to evaluate the effect of various seed rates and NPK fertilizer levels on yield parameters, overall yield, and nutrient use efficiency of wheat under the agro-climatic conditions of the cotton-wheat cropping system over two years (2020-21 and 2021-22) at the Adaptive Research Farm, Vehari, Punjab, Pakistan. The experiment included two seed rates (125 and 150 kg ha<sup>-1</sup>) and five different NPK fertilizer levels (recommended NPK of 158-114-62 kg ha<sup>-1</sup>, 12.5% increase, 12.5% decrease, 25% decrease, and 25% increase over the recommended NPK). Results showed a clear interaction between seeding rate and NPK level, with both significantly affecting yield and yield parameters across both growing seasons. The combined results indicated that the treatment with a 25% increase over the recommended NPK and a seed rate of 125 kg ha<sup>-1</sup> produced the highest grain yield of 4046 kg ha<sup>-1</sup>, while the lowest yield of 3607 kg ha<sup>-1</sup> was recorded from plots treated with 25% decrease over the recommended NPK. The highest agronomic use efficiency—1.01 kg grain per kg NPK—was also observed with the 25% increase over recommended NPK at a seed rate of 125 kg ha<sup>-1</sup>. This

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<sup>1</sup> Directorate General Agriculture (FT & AR), Punjab, Lahore; <sup>2</sup> Directorate of Agriculture (FT&AR) Vehari zone, Pakistan; <sup>3</sup> Directorate of Agriculture (FT&AR), Sheikhpura zone, Pakistan; <sup>4</sup> Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan; <sup>5</sup> Govt. College University, Faisalabad, Sahiwal Campus; <sup>6</sup> Agronomic Research Station, Farooqabad, Sheikhpura, Punjab, Pakistan; <sup>7</sup> Fertilizer sector, Punjab, Pakistan; <sup>8</sup> Department of Agriculture, Government College University, Lahore-Pakistan  
\*Corresponding author: shahbazsms2014@gmail.com

approach enhances grain yield, optimizes resource utilization, and supports sustainable wheat production practices in Pakistan.

**Keywords:** wheat, seed rate, NPK fertilizer, agronomic use efficiency, plant growth, yield

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## **Introduction**

Wheat (*Triticum aestivum* L.) in Pakistan used as staple food, contributing significantly to national food security and rural livelihoods. Wheat is cultivated on approximately 9 million hectares in Pakistan, producing around 30 million tonnes annually, nearly meeting the country's domestic demand (Iftekhhar et al., 2025). Despite its importance, wheat yields in Punjab remain below global averages due to soil nutrient depletion, sub-optimal agronomic practices, delayed sowing after cotton harvest, and climatic stresses. Among the key management factors influencing wheat productivity, seed rate and balanced nutrient application are critical for ensuring proper crop establishment and maximizing yield potential. Khaliq et al., (2019) reported that the wheat yield achieved on farmers' fields continues to lag behind potential levels, highlighting the need for improved agronomic practices and resource management. Roberts et al., (2019) also reported that fertilizers must be provided in adequate quantity so that the deficient soils can produce optimum yields. There are several underlying causes of low agricultural yields in Pakistan. To address this challenge, it is essential to reduce the yield gap by enhancing crop productivity per unit area. (Leghari et al., 2024). Imbalanced application of fertilizer affects the productivity of wheat. Our soils are deficient in NPK and potash deficiency appears rapidly (Ullah et al., 2024). So, it's crucial to apply fertilizers in a balanced approach for having economic wheat yield.

Seed rate directly influences plant population, canopy structure, tillering ability, resource competition, and ultimately the number of spikes per unit area. Improper seeding density either results in sparse stands with poor weed suppression or overly dense stands, leading to excessive intra-plant competition and smaller grain size. Finding the optimal seeding rate is crucial for achieving higher grain yields and better crop quality. Using seed rates indiscriminately increases production costs and can also reduce wheat yield (Singh et al., 2020). Seed rate impacts plant density, tiller count per square meter, thousand-grain weight, and straw yield (Shah et al., 2025). Correct seeding rate is a key factor that determines the crop's ability to efficiently capture and use available resources (Iqbal et al., 2025). Likewise, nitrogen, phosphorus, and potassium are essential macronutrients that control crop growth and yield characteristics. In many cotton–wheat areas, NPK fertilizers are often applied imprecisely, resulting in poor nutrient use efficiency, lower yields, and higher production costs. Nitrogen is vital for plant growth because it is a core component of chlorophyll, proteins, and nucleic acids (Wang et al., 2024). Lands in Pakistan frequently lack sufficient phosphorus, necessitating phosphate application for economic crop production (Aimen et al., 2022). Phosphorus promotes flowering and seed formation, and crops deficient in phosphorus tend to produce smaller grains, ultimately leading to reduced crop yields. Potassium (K<sup>+</sup>) is also critical for the crop's life cycle. It activates many enzymes, helps balance carbohydrate, protein, and fat concentrations in the plant, and enhances tolerance to drought. It also provides resistance to pests, diseases, frost, and lodging (Sardans et al., 2021). Understanding how seed rates interact with NPK fertilizer levels under the specific agro-climatic conditions of Punjab is essential to develop better recommendations for sustainable wheat production. This study assesses wheat growth, yield, and nutrient-use efficiency under different combinations of seed and NPK levels to create optimized management practices for the wheat–cotton cropping system in Pakistan.

## Materials and Methods

A field trial was conducted at Adaptive Research Farm, Vehari, Punjab, Pakistan during the winter (Rabi) season of 2020-21 and 2021-22 to access the effect of various seed rates of wheat and different NPK levels on grain yield and yield associated parameters of wheat. The treatments comprised of two different seed rates i.e., 125 kg ha<sup>-1</sup> and 150 kg ha<sup>-1</sup> with five NPK fertilizers doses viz: Recommended dose (158-114-62 N: P<sub>2</sub>O<sub>5</sub>: K<sub>2</sub>O ha<sup>-1</sup>, 12.5 % above recommended (178-128-70 kg ha<sup>-1</sup>) 12.5% below recommended (138-100-54 kg ha<sup>-1</sup>), 25% below recommended (119-86-47 kg ha<sup>-1</sup>) and 25% above recommended (198-143-78 kg ha<sup>-1</sup>). The experiment was conducted using a Randomized Complete Block Design (RCBD) with a factorial arrangement and three replications. Wheat was sown in the first fortnight of November during both years, maintaining a uniform row spacing of 22.5 cm.

All phosphatic and potash fertilizer were applied at the time of seed bed preparation, whereas nitrogen in the form of urea was provided to the crop in three equal splits; one third at sowing, one third with 1<sup>st</sup> irrigation and the remaining one third with 2<sup>nd</sup> irrigation. The soil of experimental site belonged to clay-loam textural class. The pre-sowing physio-chemical characteristics of soil are given in Table 1.

Meteorological data recorded during wheat growing season indicated that the mean maximum temperature was 32.25 °C in 2020–21 and 33.54 °C in 2021–22, while the mean minimum temperature was 5.62 °C and 5.67 °C, respectively. A total 45 mm and 22 mm rainfall was received during the crop growth period in 2020-21 and 2021-22, respectively. All other agronomic practices, including irrigation, weed control, and other crop husbandry practices were kept homogenous across all experimental units.

Standard procedures were employed for recording data on yield and yield-related measurable characteristics. At physiological maturity, wheat plants were manually harvested from a randomly selected 1 square meter area within each plot. The samples were threshed to record the number of productive tillers per square meter and grain yield (g m<sup>-2</sup>), which was subsequently converted to kilograms per hectare. The thousand-grain weight and the number of grains per spike were determined from ten randomly selected spikes taken from each plot. The mean values were analyzed using STATISTIX 8.1. Differences among treatment means were evaluated using the Least Significant Difference (LSD) test at the 0.05 probability level.

**Table1.** Soil characteristics of the experimental site

Characteristics	Value
Organic matter (%)	0.57
Total nitrogen (%)	0.039
Available phosphorous (ppm)	2.72
Available potassium (ppm)	144
pH	8.57
ECe (dS/m)	1.86
Soil textural class	Clay loam

## RESULTS AND DISCUSSION

Different NPK fertilizer levels and seed rates had a significant effect ( $p < 0.05$ ) on the number of productive tillers per square meter in both study years (Tables 2 & 3). The highest number of yielding tillers, 289 and 271, was recorded in plots where a 25% increase over the recommended NPK kg ha<sup>-1</sup> (T-5) was applied, followed by 280 and 260 from plots treated with a 12.5% increase over the recommended NPK (T-2). The lowest productive tillers, 262 and 241, were observed in plots where a 25% decrease over the

### *Response of wheat seed and NPK rate*

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recommended NPK (T-4) was applied at 125 kg ha<sup>-1</sup> for both study years. However, productive tiller numbers were lower at 150 kg ha<sup>-1</sup> across all fertilizer treatments compared to 125 kg ha<sup>-1</sup>. This may be due to the fact that optimal seed rates are critical for the wheat production system because they support tiller development. These results align with previous studies that show increasing seed rates affect the number of fertile tillers (Anum et al., 2020).

Grain yield per spike was significantly influenced ( $p < 0.05$ ) by varying NPK fertilizer rates and seed rates for both study years (Tables 2 and 3). The maximum number of grains per spike (41.4 and 40.8 for year-1 and year-2, respectively) was recorded in plots receiving a 25% increase over the recommended NPK rate (158-114-62 kg ha<sup>-1</sup>), followed by 38.8 and 38.2 grains per spike with a 12.5% increase in NPK. In contrast, the lowest grain counts (32.6 and 31.5) were observed in plots with a 25% reduction in recommended NPK in experimental units where 125 kg ha<sup>-1</sup> seed was sown. These findings align with previous research (Nakachew et al., 2025), which reported that seed rate directly affects plant population density, tiller formation, 1000-grain weight, and straw yield. The superior performance under elevated NPK levels can be attributed to enhanced nutrient availability, particularly nitrogen (N), which promotes tillering and spikelet development, while phosphorus (P) and potassium (K) improve grain filling and stress resilience (Smith et al., 2023). The 25% NPK increase likely optimized photosynthetic efficiency and carbohydrate translocation to spikes, resulting in higher grain numbers. However, further research is needed to assess the economic feasibility of exceeding recommended fertilizer rates, considering potential environmental trade-offs such as nutrient leaching or soil acidification. Various NPK and seed rates significantly influenced 1000-grain weight ( $p < 0.05$ ) during both years (Tables 2 and 3). Maximum 1000 grain weight (40.6 and 40.2 g for year 2020-21 and 2021-22 respectively) was recorded where 25% increase over recommended NPK kg ha<sup>-1</sup> was applied followed by 37.9 and 38.1 where 12.5 % increase over recommended NPK was applied while minimum (30.2 and 29.4 g) 1000-grain weight attained from the experimental units where (25 % decrease over recommended NPK) was applied along with 125 kg ha<sup>-1</sup> for both study years. It may be due to the fact that 25% increase over the recommended dose of NPK kg ha<sup>-1</sup> as soil application @ 158-114-62 kg ha<sup>-1</sup> was added in an adequate amount, which caused an increase in 1000-grain weight. The increased grain weight could be attributed to enhanced metabolic activity, which improved gluten and moisture content in the grains, thereby increasing their weight. These results are consistent with the findings of Ullah et al. (2024).

**Table 2.** Effect of seed rates and various NPK fertilizer level on the grain yield and yield parameters of wheat during 2020-21

Treatments	Plant height	Productive tillers (m <sup>-2</sup> )		Grains spike <sup>-1</sup>		1000-grain weight (g)		Grain yield		Agronomic efficiency (kg grain yield per kg NPK)		
	(cm)							(Kg ha <sup>-1</sup> )				
(N-P-K)	Seed rates (kg ha <sup>-1</sup> )											
	125	150	125	150	125	150	125	150	125	150	12	15
158-114-62	104.5c	107.4c	286a	272b	37.1c	36.8c	36.5cd	36.1d	3852c	3719d	0.59	0.41
12.5 % increase over recommended NPK	106.9c	109.6bc	280ab	275b	38.8b	37.2c	37.9c	37.5c	3937b	3825c	0.75	0.65
12.5 % decrease over recommended NPK	102.7cd	105.4c	268b	260c	35.2d	34.6d	32.0e	31.8e	3745d	3664e	0.31	0.28
25 % decrease over recommended NPK	98.7d	101.4d	262c	255c	32.6e	31.8e	30.2f	29.9f	3654e	3581f	-	-
25 % increase over recommended NPK	111.7b	115.6a	289a	278ab	41.4a	40.4a	40.6a	39.2b	4091a	3959b	1.04	0.91
LSD (p≤0.05)	5.73		8.6		1.5		1.3		41.2			

Means not sharing the same letter within a column differ significantly at ( $p \leq 0.05$ )

**Table 3.** Effect of seed rates and various NPK fertilizer level on the grain yield and yield parameters of wheat during 2021-22

Treatments (N-P-K)	Plant height (cm)		Productive tillers (m <sup>-2</sup> )	Grains spike <sup>-1</sup>		1000-grain weight (g)		Grain yield (Kg ha <sup>-1</sup> )		Agronomic efficiency (kg grain yield per kg NPK)		
	125	150		125	150	125	150	125	150			
	Seed rates (kg ha <sup>-1</sup> )											
<b>158-114-62 (recommended)</b>	101.2b	104.4b	267a	262ab	36.4c	35.6c	36.1bc	35.7c	376.2c	36.22d	0.6	0.39
<b>12.5 % increase over recommended NPK</b>	105.4a	110.8a	260b	257b	38.2b	36.2c	38.1b	37.2b	384.5b	37.28c	0.76	0.63
<b>12.5 % decrease over recommended NPK</b>	98.3c	101.4b	255b	247c	34.8cd	33.4e	33.2d	32.3d	365.0d	35.72e	0.31	0.28
<b>25 % decrease over recommended NPK</b>	95.5c	97.4c	241c	235c	31.5f	30.2f	29.4e	28.7e	356.0e	34.89f	-	-
<b>25 % increase over recommended NPK</b>	108.1a	111.3a	271a	268a	40.8a	39.4a	40.2a	39.8a	400.1a	38.65b	1.06	0.9
<b>LSD (p≤0.05)</b>	6.1		6.3		1.36		1.52		46.5			

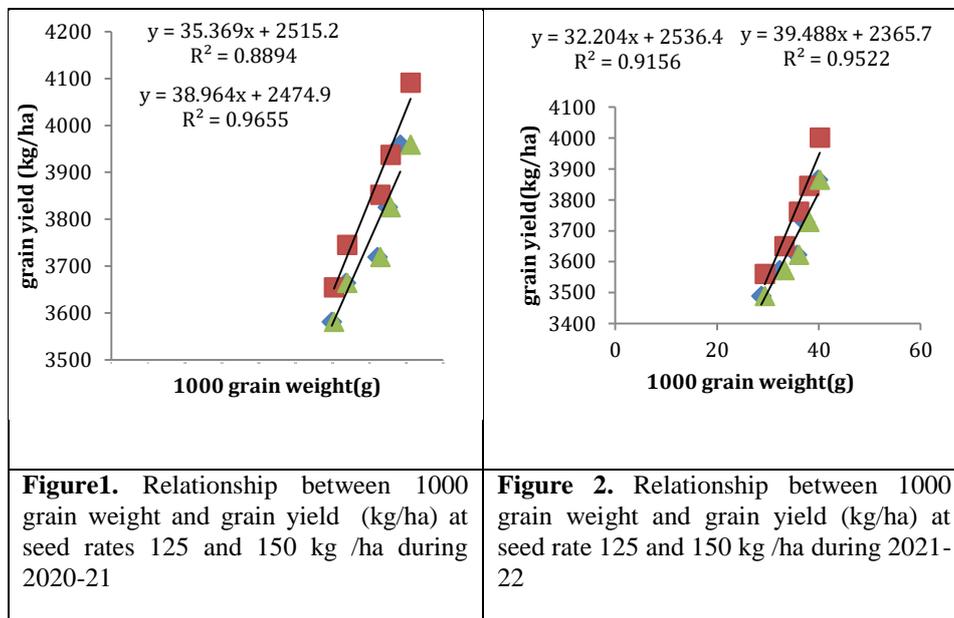
Means not sharing the same letter with in a column differ significantly at (p ≤ 0.05)

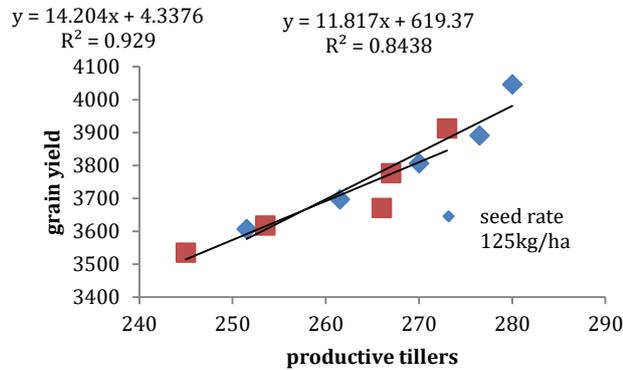
Regarding grain yield, varying NPK levels and seed rates influenced significantly ( $p < 0.05$ ) during both years (Table-2 and 3). The maximum grain yield of 4091 and 4001  $\text{kg ha}^{-1}$  was found in plots where 25% increase over recommend NPK (T-5) was applied followed by 3937 and 3845  $\text{kg ha}^{-1}$ , attained from the experimental unit supplied with 12.5 % increase over recommended NPK fertilizers (T-2) while minimum 3654 and 3560  $\text{kg ha}^{-1}$  grain yield was recorded with 25 % decrease over recommended NPK (T-4) was applied with seed rate of 125  $\text{kg ha}^{-1}$  during 2020-21 and 2021-22 respectively.

A seed rate of 125  $\text{kg ha}^{-1}$  performed best across all yield-contributing traits. This improvement may be attributed to the application of NPK at 158-114-62  $\text{kg ha}^{-1}$ , which enhanced soil fertility in plots that were otherwise deficient in nitrogen, phosphorus, and potassium, thereby increasing grain yield (Khan *et al.*, 2018).

Different NPK and seed rates also significantly influenced agronomic efficiency (kg grain yield per kg NPK fertilizer) during both years (Tables 2 and 3) ( $p < 0.05$ ). Highest Agronomic efficiency of 1.04 and 1.06 kg grain yield per kg NPK was noted in plots where 25% increase over recommended NPK fertilizers was applied, followed by 0.75 and 0.76 kg grain yield per kg NPK attained where 12.5 % increase over recommended NPK was applied with seed rate of 125  $\text{kg ha}^{-1}$  during 2020-21 & 2021-22, respectively.

A strong positive relationship was observed between thousand-grain weight and grain yield, with  $R^2$  values of 0.88 and 0.96 for 2020–21, and 0.91 and 0.95 for 2021–22 at seed rates of 125 and 150  $\text{kg ha}^{-1}$ , respectively (Figs. 1 and 2). Similarly, a significant relationship was observed between fertile tillers and wheat grain yield, with  $R^2$  values of 0.92 and 0.84 for the average data of both years at seed rates of 125 and 150  $\text{kg ha}^{-1}$ , respectively (Fig. 3). These results are in agreement with the findings of Nizamani *et al.* (2014).





**Figure 3.** Relationship between productive tillers and grain yield at seed rate of 125,150kg/ha (two-year mean data)

### Conclusion

This study showed that both seed rate and NPK fertilizer significantly affect wheat yield and its components in the cotton–wheat system of Punjab. The combination of 125 kg ha<sup>-1</sup> seed rate with a 25% increase over the recommended NPK proved most effective. Adopting a moderate seed rate with balanced NPK application is therefore recommended to maximize wheat productivity and help farmers improve input efficiency.

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