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Effect of NPK Fertilizer and Biofertilizer on Growth and Yield of Late-Sown Wheat (Triticum aestivum L.) Varieties in Khyber Pakhtunkhwa, Pakistan

Umar Farooq
Department of Soil and Environmental Sciences, The University of Agriculture, Peshawar, Pakistan. umarfarooq@aup.edu.pk
Fazli Jalal
Department of Soil and Environmental Sciences, The University of Agriculture, Peshawar, Pakistan. fazlijalal7@gmail.com
Muhammad Shafiq
Department of Agronomy, The University of Agriculture, Peshawar, Pakistan
Shafiqkhan@aup.edu.pk
Salman Khan (Corresponding author)
Department of Environmental Sciences, University of Peshawar, Peshawar, Pakistan
salmankhan2025@uop.edu.pk
Sawaira Bibi
Department of Soil and Environmental Sciences, The University of Agriculture, Peshawar, Pakistan. bibisawaira94@gmail.com
Asia Khan
Department of Soil and Environmental Sciences, The University of Agriculture, Peshawar, Pakistan. factionkhan98@gmail.com

ABSTRACT

Wheat yield is constrained by late sowing in Khyber Pakhtunkhwa due to short vegetative period and reliance on efficient nutrient supply. To assess the performance of two wheat varieties Gulzar-19 and Pirsabak-19 to mineral NPK and biofertilizer application in late sowing, a field experiment was conducted at Cereal Crops Research Institute (CCRI), Pirsabak, Nowshera 2020-2021. The experiment was laid out in randomized complete block design (split plot) and replicated three times. The varieties were laid in main plots while five fertilizer treatments were laid in sub-plots, which consisted of 60-45-30 kg N-P2O5-K2O ha^{-1}, 120-90-60 kg N-P2O5-K2O ha^{-1}, 240-180-120 kg N-P2O5-K2O ha^{-1}, biofertilizer only and 60-45-30 kg N-P2O5-K2O ha^{-1} with biofertilizer. The plant height, productive tillers, grain spike^{-1}, grain 1000 weight, biological yield and grain yield were observed and harvest index was calculated from the observed yield data. All growth and yield parameters were significantly improved by the use of fertilizers. The highest pooled grain yield (2982.5 kg ha^{-1}), biological yield (8432.0 kg ha^{-1}), productive tillers (291.1 m-2), grains spike^{-1} (55.4) and 1000-grain weight (47.8 g) were recorded with 240-180-120 kg N-P2O5-K2O ha^{-1}. The application of double NPK resulted in 35.3% and 35.9% higher grain yield and biological yield respectively than that of half NPK. The yield of grain in Pirsabak-19 was slightly higher

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than Gulzar-19. It is recommended that adequate and optimal NPK level is critical for maintaining productivity of late sown wheat crops and biofertilizer containing ½ NPK can be a moderate nutrient saving option in situations where the fertilizer cost is a constraint.

Keywords— biofertilizer; grain yield; late sowing; NPK; Pirsabak-19; wheat

Introduction

Wheat (Triticum aestivum L.) is one of the major cereal crops and of prime importance in the food security scenario of Pakistan. The crop is a major source of grain for human consumption, an important part of the national cropping system and plays an important role in rural livelihoods. The Pakistan Economic Survey 2024-25 estimated wheat production at 28.98 million tonnes with an average yield of 3,193 kg ha-1, while pointing out dry spells, high temperature at sowing and acreage reduction as some of the key factors contributing to the reduction in production from the previous year (Government of Pakistan, 2025). Efficient nutrient management is especially critical to meet the challenges of unstable wheat yields under varying climate and planting dates. Beyond climate and sowing time, agricultural sustainability in Khyber Pakhtunkhwa also depends on broader environmental monitoring and locally adapted crop-management practices. Regional studies have reported spatial variation in the physicochemical and biological quality of water resources (A. A. Khan et al., 2025; S. Khan & B. Khan, 2026). Field research has also shown that pest abundance and management effectiveness can vary across seasons and locations (Rehman et al., 2026). Although these studies addressed different environmental and crop-protection components, they collectively highlight the importance of location-specific management in regional agricultural systems.

The most important macronutrients that wheat needs for growth and yield formation are nitrogen, phosphorus and potassium. Nitrogen plays a role in vegetative growth, development of leaf area, chlorophyll production and protein synthesis. Phosphorus enhances root growth, energy transfer and early crop establishment, and potassium controls stomatal activity, enzyme activation, water relations and stress tolerance. Recently, a global meta-analysis found that both N rates and timing of N application had significant impacts on wheat yield, and that soil properties and climate conditions influenced the effects of N fertilization (Yokamo et al., 2023). Also, winter wheat (Andrzejewska et al., 2025) showed an increased grain yield, nitrogen recovery and yield stability in response to balanced fertilization with potassium and magnesium. So, balanced fertilization is better than super-charging one nutrient.

Recent local evidence also supports integrated nutrient management in cereal production. Farooq et al. (2026) reported that phosphorus applied with biochar and poultry manure improved maize yield and phosphorus-use efficiency. Although the crop species and nutrient treatments differed from the present experiment, these findings demonstrate the importance of combining adequate mineral nutrients with suitable organic amendments to improve cereal productivity.

If sown late, less time for tillering, vegetative growth and filling of grain. In this environment, nutrient availability is even more critical, as plant establishment is short

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and plants need to stay photosynthetically active during a shorter period. Low fertilizer productivity in Pakistan and other semi-arid regions is often due to sub-optimal fertilizer applications, high costs of fertilizers and delayed nutrient release in relation to crop needs. Balanced NPK management could mitigate some of these limitations through increased tiller formation, spike fertility, grain filling and final grain yield.

Biofertilizers are also included in the list of important components of integrated nutrient management. Microbial inoculants like Trichoderma and plant growth promoting rhizobacteria are able to enhance nutrient solubilization, root growth and stress tolerance by biological mechanisms. The effectiveness of the biofertilizers is however, influenced by the soil condition, crop variety, quality and quantity of mineral fertilizer supplied, and quality of the biofertilizers. Mineral fertilizer can be combined with biofertilizer to enhance nutrient use and to lower the requirement of large quantities of mineral fertilizer, but field validations should be conducted to recommend such combination to the farmers.

Beneficial microorganisms used with organic soil amendments have also shown potential for improving crop growth. Jalal et al. (2026) found that biochar-assisted Bacillus inoculation enhanced maize growth while reducing cadmium and lead bioavailability. Similarly, A. Khan et al. (2026) reported that spent mushroom substrate biochar combined with plant growth-promoting rhizobia alleviated heavy-metal toxicity and improved maize performance. Although these studies were conducted under contaminated soil conditions, they demonstrate the ability of microbial inoculants and organic carriers to support plant growth and nutrient acquisition.

The effect of various levels of NPK fertilizer and biofertilizer was therefore evaluated during the present study on growth and yield of two late-sown varieties of wheat. To evaluate the response of Gulzar-19 and Pirsabak-19 to fertilizer treatments, to find the most optimum level of fertilizer application for the best growth and yield performance and to report the findings in a research paper format along with yield indicators and professional graphical interpretation.

Materials and Methods

Experimental site

The field experiment was carried out at the Cereal Crops Research Institute (CCRI), Pirsabak, district Nowshera of Khyber Pakhtunkhwa Province, Pakistan during winter 2020-2021. The experimental site is situated in the region of 34° N latitude, 72° E longitude and an average elevation of 288 m above sea level. This trial was sown in late sowing conditions and sowing was carried out on 20 December 2020.

Experimental design and treatments

The experimental design used in the present experiment was randomized complete block design with a split-plot design and three replications. Main plots were wheat varieties and sub-plots were fertilizer treatments. The plot size was 5 m × 2 m and total experimental plots was 30. Gulzar-19 and Pirsabak-19 were the varieties of wheat. The fertilizer treatments are given in Table 1.

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Table 1 Wheat varieties and fertilizer treatments used in the field experiment.

Factor	Level	Description
Variety	V1	Gulzar-19
Variety	V2	Pirsabak-19
Fertilizer	F1	60-45-30 kg N-P2O5-K2O ha-1
Fertilizer	F2	120-90-60 kg N-P2O5-K2O ha-1
Fertilizer	F3	240-180-120 kg N-P2O5-K2O ha-1
Fertilizer	F4	Biofertilizer only
Fertilizer	F5	60-45-30 kg N-P2O5-K2O ha-1 + biofertilizer

Urea, diammonium phosphate (DAP) and sulphate of potash (SOP) were used as sources of N, P and K, respectively. Trichoderma based green soil inoculant was used as the source of biofertilizer. The nitrogen was split applied at sowing, tillering and booting while phosphorus and potassium were split applied at sowing. Irrigation, land preparation and manual weed control were done in accordance with the crops requirement and local recommendations.

Data recording

Plant height (cm), productive tillers m^{-2}, grains spike^{-1}, 1000-grain weight (g), biological yield (kg ha-1) and grain yield (kg ha-1) were measured. Plant height from base to top of spike was determined at physiological maturity. The number of productive tillers was counted in randomly selected rows and adjusted to m^{-2}. Five plants were randomly selected in each plot and grains spike^{-1} were counted. A sample of seeds was taken at random from the seed sample and the Thousand-grain weight was measured with the weighing balance. The biological yield and grain yield have been adjusted to kg/ha of the dry area harvested.

Statistical and graphical analysis

Analysis of variance was used to statistically analyze the original experiment and treatment differences were compared using LSD of 5% probability. The data from each of the appendices was duplicated and reorganized for the present paper in order to determine treatment means, standard errors, and another derived index. Harvest index (HI) was defined as grain yield/biological yield x 100. Because no synthetic treatment observations were added, all numerical results are based on observed field data and the additional harvest index variable was calculated from the existing yield data. The graphs were created in a publication ready SPSS-style format with mean ± SEM.

Results

Analysis of variance

The analysis revealed that there were significant differences in the wheat growth and yield among the fertilizer treatments, while the differences among the varieties were smaller but significant for productive tillers, 1000-grain weight and yield. The interaction between the varieties and fertilizers was greatest for biological yield, indicating that the fertiliser level did not affect the two varieties in the same way for

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production of biomass. The summary of p-values is given in Table 2 which is compact.

Table 2 Compact ANOVA p-value summary for growth and yield parameters.

Parameter	Variety	Fertilizer	Variety × fertilizer
Plant height (cm)	0.503	<0.001	0.918
Productive tillers (m-2)	0.028	<0.001	0.332
Grains spike-1	0.125	<0.001	0.846
1000-grain weight (g)	<0.001	<0.001	0.106
Biological yield (kg ha-1)	<0.001	<0.001	<0.001
Grain yield (kg ha-1)	<0.001	<0.001	0.675
Harvest index (%)	<0.001	0.511	<0.001

Values below 0.05 indicate statistically meaningful treatment effects in the rechecked factorial analysis. The original report used split-plot ANOVA and LSD comparison.

Effect of fertilizer levels on growth traits

Table 3 Fertilizer-wise means for wheat growth and yield traits.

Treatment	Plant height (cm)	Tillers (m-2)	Grains spike-1	1000-grain weight (g)	Biological yield (kg ha-1)	Grain yield (kg ha-1)	Harvest index (%)
F1	78.0	225.0	50.3	39.4	6204.0	2203.7	35.52
F2	80.5	263.2	53.6	45.2	7548.2	2677.2	35.49
F3	85.4	291.2	55.5	47.9	8432.0	2982.5	35.37
F4	79.4	240.8	52.6	44.2	7129.2	2515.5	35.29
F5	80.3	266.2	53.7	45.3	7419.5	2633.5	35.50

F1=60-45-30 N-P2O5-K2O kg ha-1; F2=120-90-60 N-P2O5-K2O kg ha-1; F3=240-180-120 N-P2O5-K2O kg ha-1; F4=biofertilizer; F5=60-45-30 N-P2O5-K2O kg ha-1 + biofertilizer.

The addition of the NPK level influenced the plant height that increased with an increasing NPK level and attained the highest mean value of 85.4 cm in F3. The mean plant height was smallest in F1. The plant height was found to be 9.5% higher in F3 than in F1 which indicates that with sufficient and balanced nutrient supply, late sowing led to better vegetative growth. The effect of the half NPK + biofertilizer treatment (F5) was slight in terms of plant height when compared to F1, but was comparable to the recommended NPK fertilizer treatment for some traits.

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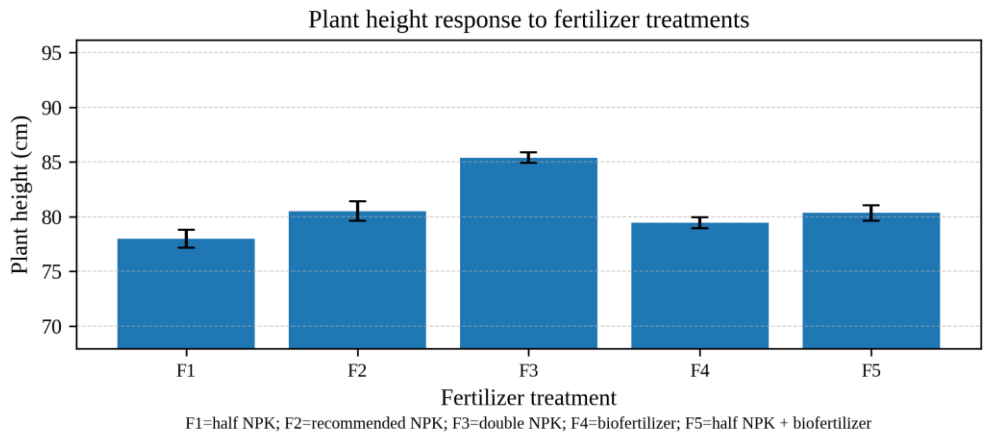

Figure 1 Effect of fertilizer treatments on plant height of wheat under late-sown conditions.

Productive tillers exhibited more response to fertilizer management compared with plant height. The best tillers (291.2 m-2) were obtained from the F3 followed by F5 and F2. The rise from F1 to F3 was 29.4% which showed a positive effect of high levels of NPK for tiller survival and increase in tiller with spike bearing.

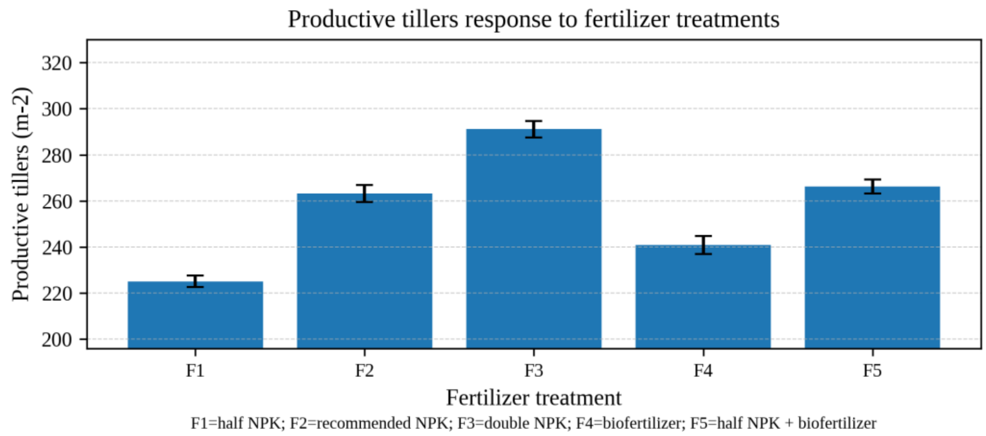

Figure 2 Effect of fertilizer treatments on productive tillers of wheat.

Effect of fertilizer levels on yield components

Fertilizer level also had a beneficial effect on grains spike^{-1}. The maximum grains spike^{-1} (55.5) was observed with F3 and the minimum (50.3) was observed with F1. This response indicated a greater nutrient availability during reproductive development led to greater spike fertility and grain formation.

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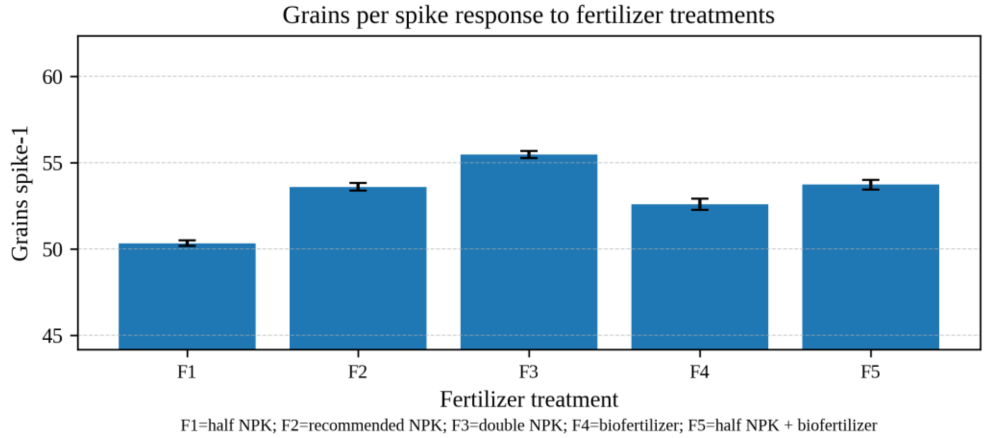

Figure 3 Effect of fertilizer treatments on grains per spike of wheat.

Thousand-grain weight varied between 39.4 g in F1 and 47.9 g in F3. The increase in grain weight under F3 is indicative of improved grain filling, and this may have correlated with increased nutrient availability during the grain development phase as well as better source:sink relationships.

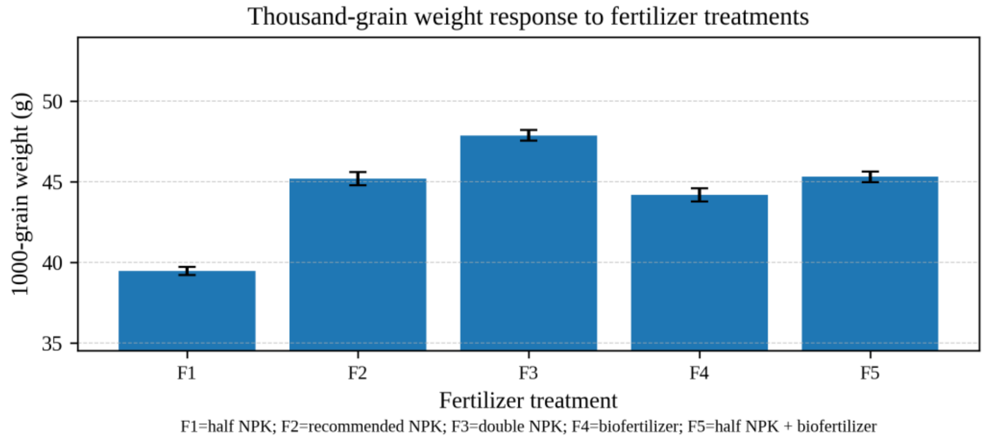

Figure 4 Effect of fertilizer treatments on thousand-grain weight of wheat.

Biological yield, grain yield and harvest index

The biological yield was responsive to the level of fertilizers. The pooled maximum biological yield (8432.0 kg ha-1) was obtained with F3 and the minimum yield (6204.0 kg ha-1) was obtained with F1. Biomass was significantly greater for Pirsabak-19 than Gulzar-19 under maximum fertilizer rate (F3). This shows that the variety was more efficient in utilizing nutrients to produce above-ground dry matter under late sowing conditions.

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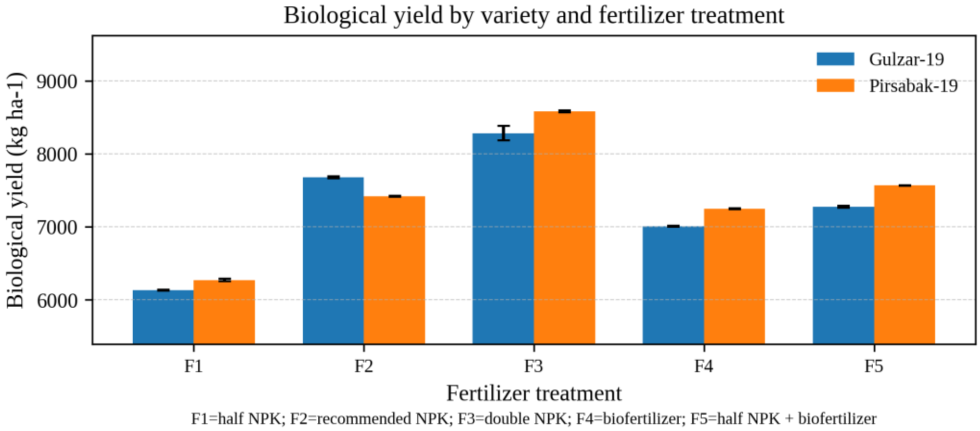

Figure 5 Interaction of wheat variety and fertilizer treatment for biological yield.

Grain yield was very similar to biological yield. The highest mean grain yield (2982.5 kg ha^{-1}) was achieved with F3, followed by F2 (2677.2 kg ha^{-1}) and F5 (2633.5 kg ha^{-1}). The lowest grain yield (2203.7 kg ha^{-1}) was obtained in F1. Grain yield of half NPK + biofertilizer was significantly higher than of half NPK alone by 19.5% indicating that biofertilizer performed better with lower NPK application, but not as well as double NPK.

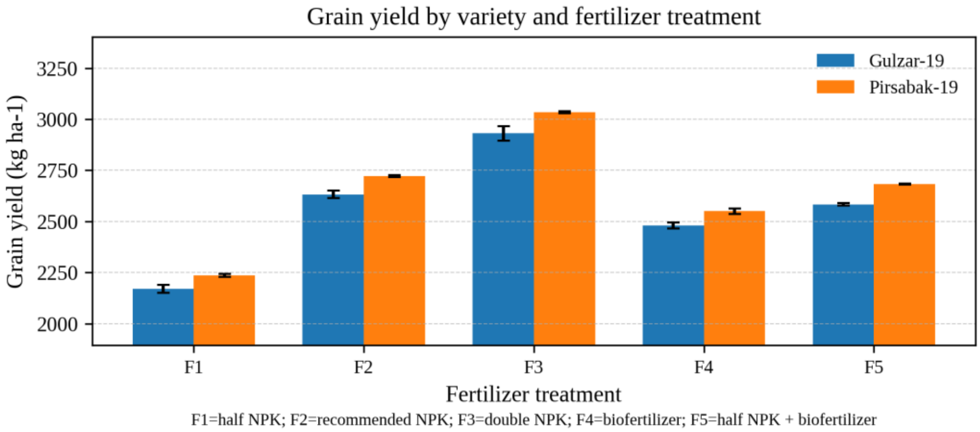

Figure 6 Interaction of wheat variety and fertilizer treatment for grain yield.

Harvest index was not significantly different among the fertilizer treatments, as grain yield and biological yield were correlated. F1 had the highest mean harvest index (35.52%) and F3 a harvest index of 35.37. This suggests that as the main advantage of F3 was for biomass production and grain number rather than a significant change in dry matter partitioning.

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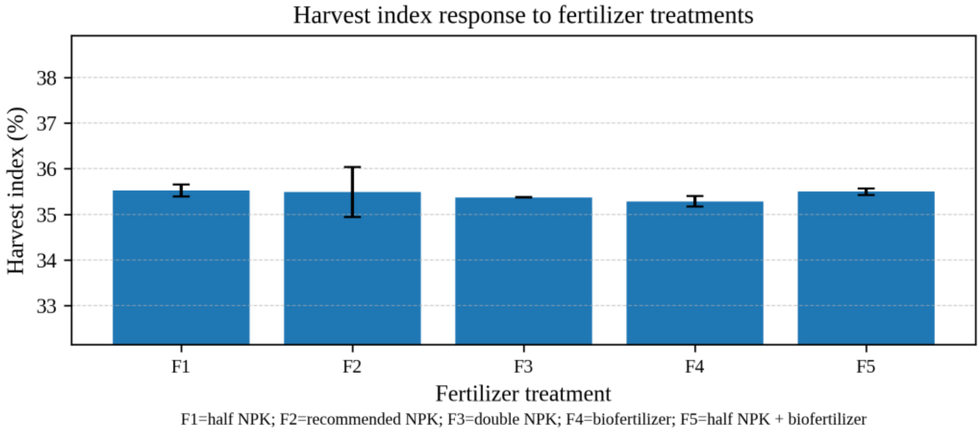

Figure 7 Harvest index of wheat as influenced by fertilizer treatments.

Varietal performance

Table 4 Varietal means across fertilizer treatments.

Variety	Plant height (cm)	Tillers (m-2)	Grains spike-1	1000-grain weight (g)	Biological yield (kg ha-1)	Grain yield (kg ha-1)	Harvest index (%)
Gulzar-19	80.5	254.1	53.3	43.8	7275.5	2559.7	35.20
Pirsabak-19	81.0	260.5	53.0	45.0	7417.6	2645.2	35.67

The productive tillers, 1000 grain weight, biological yield and grain yield of Pirsabak-19 were found to be higher when compared with Gulzar-19. The advantage was low but consistent which indicated that Pirsabak-19 is more suitable to late sowing condition at Pirsabak, Nowshera. There were no differences in plant height or grains spike-1 between the two varieties which would suggest that the yield difference was primarily due to tiller production, grain filling and biomass accumulation.

Discussion

Under late sowing conditions, the results clearly indicate that the most important factor was the amount and application of fertilizer. The progressive effect on plant height, productive tillers, spike-1, spike-10, spike-100 and 1000-grain weight and yield with increased levels of NPK suggests that nutrient supply was a limiting factor at the experimental site. There's limited time for vegetative growth of late-sown wheat, so adequate early nutrient availability will help establish the crop quickly, tillering and canopy. The production of the highest grain level at F3 indicates a positive response to the availability of NPK in the crop.

The increased growth response was likely due to nitrogen, which is directly associated with the formation of chlorophyll, protein production and canopy development. Increased N supply may lead to enhanced tiller production and photosynthetic area, leading to elevated production of assimilates. Phosphorus could have contributed to better early root establishment and energy transfer, and potassium to better water

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regulation, enzyme activation and grain filling. Recent synthesis also reveals that wheat yield response to nitrogen is especially sensitive to the N rate, timing, and to soil climate (Yokamo et al., 2023); that balanced nutrient strategies based on N, P and K can help to enhance yield stability and nutrient recovery (Andrzejewska et al., 2025).

Comparable evidence was reported by Farooq et al. (2026), who observed improved maize yield and phosphorus-use efficiency when phosphorus was integrated with biochar and poultry manure. The crop and amendment system differed from the present wheat experiment, but both studies indicate that adequate nutrient supply and integrated soil amendments can improve cereal productivity.

Agronomically, the performance of the half NPK + biofertilizer treatment is important. No significant differences were noted between yield of F5 and half NPK alone, but F5 improved grain yield over half NPK alone. This indicates that biofertiliser can be used to help release nutrients or root activity when mineral fertiliser is used in low rates. The response, however, was not as large as to supplant the need for adequate mineral NPK under the conditions of this experiment. To be more practical, it is recommended to use biofertilizer as an alternative to balanced fertilizers instead of complete replacement.

The response observed with half NPK plus biofertilizer is consistent with the wider role of beneficial microorganisms in improving plant performance. Biochar-assisted Bacillus inoculation enhanced maize growth (Jalal et al., 2026), while plant growth-promoting rhizobia combined with spent mushroom substrate biochar also improved crop growth under soil stress (A. Khan et al., 2026). These findings support the use of microbial inputs as complementary components of nutrient management rather than complete replacements for mineral fertilizers.

The variety performance revealed that Pirsabak-19 gave slightly better performance than Gulzar-19 in terms of grain yield and biomass production. This difference could be associated with higher tillering capacity and grain filling ability. However, late sown wheat has shown favourable responses to F3 so the focus should still be on fertilizer management. A combination of a well-adapted variety, balanced fertilization (NPK) and split fertilization of the nitrogen is a way for farmers to achieve higher yields.

The harvest index data indicate that higher yield in F3 was mainly due to increased biomass and yield components and not primarily due to a significant increase in partitioning efficiency. This is supported by an increase in biological yield, tillers and grain yield in F3. Hence, appropriate management of increased early crop growth along with maintaining the grain filling is necessary to enhance the productivity of wheat in the late-sown condition.

Conclusion

The study has found that balanced and higher rates of NPK application had significant positive effects on growth and yield of late sown wheat varieties. The fertilizer treatments that produced the highest plant height, productive tillers, grains spike-1, 1000-grain weight, biological yield and grain yield were 240-180-120 kg N-P2O5-K2O ha-1. The treatment increased grain yield by 35.3% over half NPK, highlighting the need for good nutrient supply in late-sown situations. The performance of Pirsabak-19 was slightly better than Gulzar-19 in terms of the productive tillers, biological yield and grain yield. Half NPK + biofertilizer gives better yield than half NPK alone, but it could not outperform yield advantage of adequate mineral NPK. In general, the use of double

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NPK was found to produce the highest yield, while half the application of NPK and biofertilizer can be used as a medium input-saving fertilizer application in response to the availability and cost of fertilizers.

Recommendations

Use Pirsabak-19 with 240-180-120 kg N-P_2O_5-K_2O ha^{-1} and biofertilizer for higher late-sown wheat yield. Further trials should confirm its economic feasibility.

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