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Research Article

Enhancing Wheat (*Triticum aestivum* L.) Growth through Farmyard Manure Application of Potassium Fertilizer

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Abstract

The results of a field experiment on wheat Sindhu revealed that the combined utilization of chemical fertilizers and organic sources of nutrients, such as farmyard manure, led to greater effectiveness in comparison to using chemical fertilizers alone. The experiment employed a split plot design, with specific rates of potassium (0, 60, & 90 kg K_2O ha^{-1}) as the sub-split, and farmyard manure as the primary division. The soil utilized in the study demonstrated normal levels of pH and electrical conductivity (EC), but exhibited deficiencies in organic matter and Kjeldahl's N. Moreover, the availability of plant nutrients like P and K was found to be marginal. Notably, the investigation concluded that all parameters associated with yield, including. The combined utilization of farmyard manure and potassium (K) rates exhibited a noticeable influence on various aspects of crop growth and nutrient uptake, including seed quality, grain and straw production, K content, and related absorption. The application of 90 kg K_2O ha^{-1} and 15 tons of farmyard manure resulted in the highest values for grain yield, phosphorus uptake, and other parameters (excluding plant height and number of spikes per plant). However, statistically significant differences were observed when comparing the combination of 15 tons of farmyard manure with 60 kg K_2O ha^{-1} against 10 tons of farmyard manure with 90 kg K_2O ha^{-1}.According to the study, the maximum efficiency of potassium utilization (3.1 kg kg^{-1}) was reported when 60 kg of potassium dioxide ha^{-1} was mixed with 15 tons of farmyard manure ha^{-1}. Interestingly, the efficiency remained constant at 3.0 kg kg^{-1} when 60 kg K_2O ha^{-1} was combined with 10 tons of farmyard manure. Increasing the potassium rate from 60 to 90 kg K_2O ha^{-1} and the amount of farmyard manure from 10 to 15 tons ha^{-1} did not significantly improve wheat yield or potassium absorption. In conclusion, the findings suggest that utilizing 60 kg K_2O ha^{-1}

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with 10 tons of farmyard manure is a viable approach. However, further research is needed to explore the optimal combination of K rates and farmyard manure quantities for maximizing crop productivity and nutrient uptake.

Keywords: Farmyard Manure; Growth; Potassium; Wheat; yield

Introduction

Wheat is the most significant crop in Pakistan, particularly in the regions of Punjab and Sindh where it is grown during the Rabi season it provides the populace with a basic food (Anjum *et al.*, 2020). It has a lot of protein, vitamins, and carbohydrates, providing essential nutrition to millions of people. In India, wheat cultivation covers a vast area of approximately 29.14 million hectares, making it the largest cultivation area globally, although it ranks second in terms of production (Abid *et al.*, 2018).Wheat is a Rabi crop, started in October to December and obtained from March to May in Pakistan. The straw produced from wheat plants has various potential uses, such as biomass material for bioenergy or as organic fertilizer (Riaz *et al.*, 2022). The quantity of wheat grain's proteins is influenced by factors such as genotype, soil and atmospheric circumstances and crop-management techniques. While genetic factors play a significant role, external factors such as precipitation and cultivation practices also contribute to protein content variation (Wahid *et al.*, 2015). Potassium is a nutrient that plants absolutely require and the third key component of commercial fertilizers. It plays a crucial part in improving crop yields, improving disease resistance, and strengthening the root system of plants (Chen *et al.*, 2018). Including potassium in the fertilizer schedule has been shown to improve wheat outcomes, including taller plants, thicker grains, and higher grain weight. Potassium has a broad range of functions in plants, including enzyme stimulation, regulation of osmotic pressure, photosynthesis, stomatal movement, energy drive, and maintaining cation-anion balance in the soil. It also helps plants withstand stress (Townsend *et al.*, 2018). Farmyard manure is a traditional soil amendment practice that positively affects soil properties and fertility. It enhances physical fitness of the soil, including its capability for retaining water, and provides both micro and macronutrients (Wang *et al.*, 2016). Farmyard manure also increases soil moisture storage, making it a valuable resource for sustainable land utilization. Organic materials, such as compost and decomposed crop residues, are important for enhancing soil fertility and nutrient status, especially considering the rising prices of synthetic fertilizers. The combination of farmyard manure with chemical fertilizers has been shown to increase yield and nutrient uptake, improving the efficiency of chemical fertilizers (Adisa *et al.*, 2019). Incorporating organic matter into salt-affected soils can improve soil infiltration and facilitate leaching of salts, leading to a decrease in electrical conductivity values of the soil (Yahya *et al.*, 2022). This highlights the potential of organic amendments in improving the quality of salt-affected soils (Manzoor *et al.*, 2019). Overall, the mix of organic additives, such as farmyard manure, and chemical fertilizers can have significant benefits for wheat cultivation, including improved yield, nutrient uptake, and soil fertility (Bhatt *et al.*, 2019).

Methodology

An experiment was carried out in the field at the Agriculture Research Institute's Experimental Field in Tandojam to find out how potassium fertilizer and farmyard manure application rates affected wheat growth, yield, and potassium absorption. This study was conducted at Tandojam to investigate the impact of weather conditions on the growth and development of wheat crop. Impact of variations in the meteorological

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parameters on different phenological phases and hence on final yield of wheat crop was analyzed. The setup of the experiment as a split-plot design, with varied amounts of FYM (0, 10, and 15 tonnes ha^{-1}) applied to the main plots and variable amounts of potassium (0, 60, & 90 kg K_2O ha^{-1}) put into the sub-plots. Three copies of the experiment were carried out. According to the treatment instructions, decomposed farmyard manure was added to the soil, thoroughly mixed, and then allowed to soak and the soil type is Clay Loam. Wheat seeds were seeded after a month of incorporating farmyard waste at Season of Rabi. At planting, the full recommended amount of urea (120 kg ha^{-1}) and the appropriate amount of DAP (90 kg P_2O5 ha^{-1}) were applied. Three equally sized portions of the leftover urea were administered during the crop's development phases. With the use of a single counter hand drill, rows of the wheat cultivar Sindhu were seeded. Plants were spaced 2.25 cm apart from one another, and rows where 30 cm. Irrigation is provided by perennial canal and supplemented by tubewells. The number of irrigations given to wheat varied from 3 to 8, with an average of 5 irrigations apart. The appropriate agronomic procedures were followed throughout the trial, and steps were taken to manage disease and insect pests. When the crop was ready, it was harvested.

Statistical analysis

The collected data from the experiment was organized in a spreadsheet using Microsoft Excel. The data was then imported into the statistical analysis software Statistix 8.1 (Analytical Software, 2005) for further analysis. The statistical analysis was performed by treating farmyard manure is the primary element and potassium rates as the sub-factor in a split-plot design. If a parameter showed significance based on the analysis of variance (ANOVA) table, taking into account both the individual parameters and their combinations, the means of the data were compared using LSD (Least Significant Difference) values.

Results

Plant height

The study's findings showed a considerable difference ($p<0.05$) in the growth of wheat plants at various levels of potassium fertilizer and farmyard manure. Increasing the amount of farmyard manure, potassium rates, or their combination resulted in an increase in plant height. Wheat plants showed the tallest height (90.66 cm) when treated with 15.00 tons ha^{-1} of FYM, go alone with by 10.00 tons ha^{-1} (89.02 cm), while the control group without farmyard manure had a height of 84.89 cm. Similar patterns were observed for different potassium fertilizer rates. Plants exhibited a greater height (90.78 cm) when treated with 90 kg K_2O ha^{-1}. As the potassium fertilizer rate decreased to 60 kg K_2O ha^{-1}, the plant height slightly decreased to 88.70 cm. The minimum height was recorded in the control group (85.08 cm) where zero potassium fertilizer was applied.

The wheat plants reached their maximum height of 93.33 cm when farmyard manure was applied at a rate of 15 tons ha^{-1} along with a potassium fertilizer rate of 90 kg K_2O ha^{-1}. On the other hand, the control group, which did not receive any farmyard manure or potassium fertilizer, had the lowest plant height at 82.67 cm. This demonstrates that the combination of farmyard manure and potassium fertilizer greatly influences the height of wheat plants.

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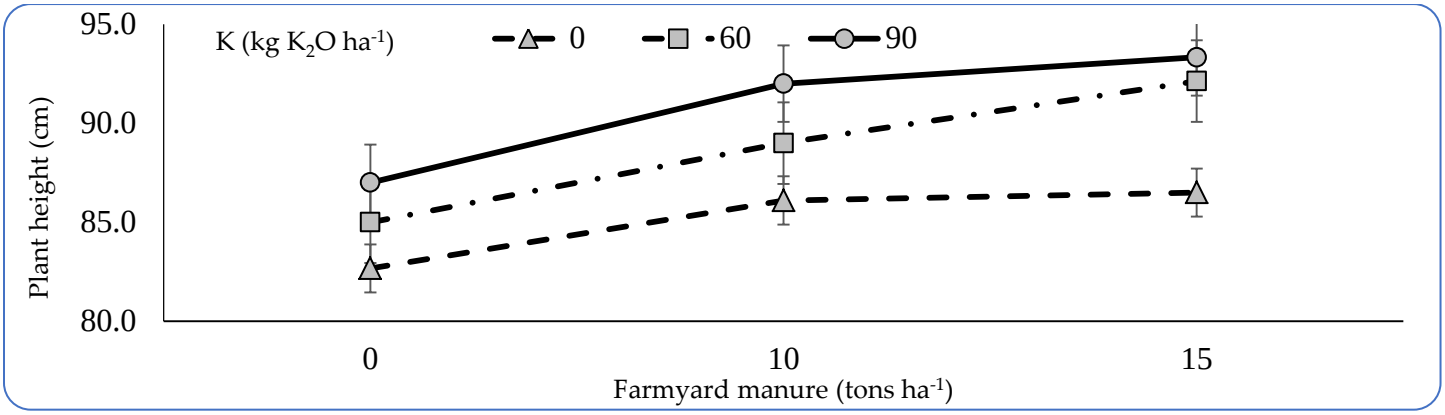

Parameters	Mean of squares	F value	LSD @ 0.05
FYM	78.593	0.48 NS	15.753
K-rates	73.632	0.63 NS	12.081
FYM× K-rates	2.762	0.03 NS	21.776
Non-Significant			

Figure 1. Wheat height as a function of potassium and farmyard manure rates. Squared means, significant F values, and LSD for plant height.

Tillers plant^{-1}

The application of farmyard manure (FYM) and potassium fertilizer resulted in a significant increase in the number of tillers in wheat. In the control group, which did not receive FYM but had NP application, there were 1014 tillers plant^{-1}. However, when 15 tons of FYM ha^{-1}were used, the number of tillers increased to 10.90 plant^{-1}. Similarly, the application of potassium fertilizer also led to a notable increase in tiller count. The control group had 10.16 tillers, while the groups treated with 60 kg K_2O ha^{-1} and 90 kg K_2O ha^{-1} had 10.66 and 10.87 tillers plant^{-1}, respectively. When farmyard manure and potassium fertilizer were combined, there were significant variations in tiller numbers. The highest number of tillers (11.31 plant^{-1}) was observed when 15 tons of FYM ha^{-1}and 90.00 kg K_2O ha^{-1} were applied. Interestingly, applying 10.00 tons of FYM ha^{-1}with 90.00 kg K_2O ha^{-1} (12.02 tillers plant^{-1}) and 15.00 tons of FYM ha^{-1}with 60.00 kg K_2O ha^{-1}(12.07 tillers plant^{-1}) showed similar outcomes in terms of tillers. Compared to the tiller count obtained with the other treatments, both of these interventions were statistically insignificant when compared to the combination of 15.00 tons of FYM ha^{-1} and 90.00 kg K_2O ha^{-1} (11.31 tillers plant^{-1}) in one hectare.

Spike length

Based on the use of K fertilizer and farmyard waste, the wheat plants' spike length varied. Farmyard manure at a rate of 15 tonnes ha^{-1} year^{-1} produced the longest spikes (9.46 cm), followed by 10 tonnes ha^{-1} year^{-1}. (9.26 cm), while the control group without farmyard manure had a spike length of 8.80 cm. similar patterns were observed for different rates of potassium fertilizer. The highest spike length (9.44 cm) was achieved when 90.00 kg K_2O ha^{-1} was applied, whereas the spike length slightly decreased to 9.26 cm when the potassium fertilizer rate was reduced to 60 kg K_2O ha^{-1}. The maximum

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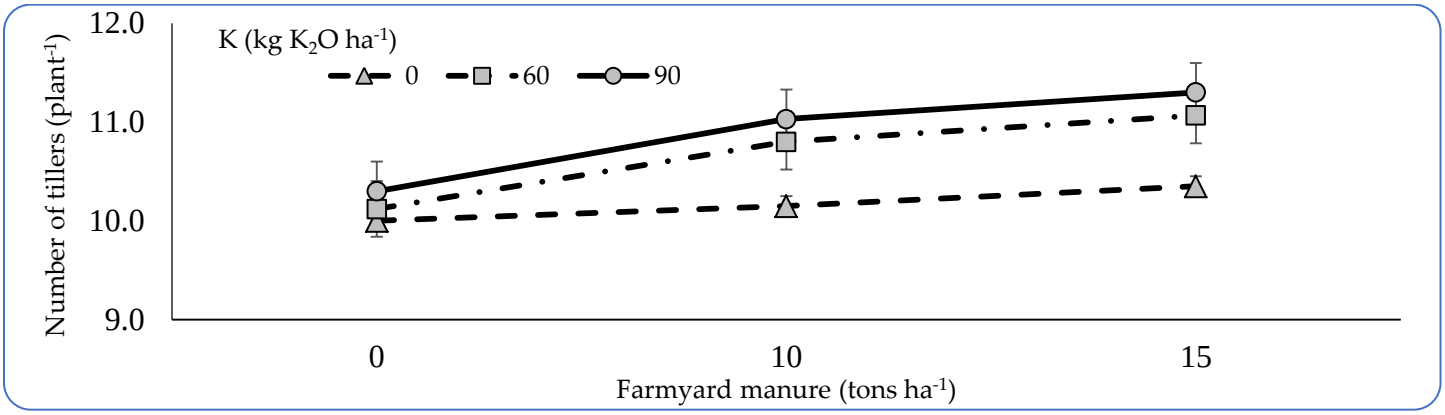
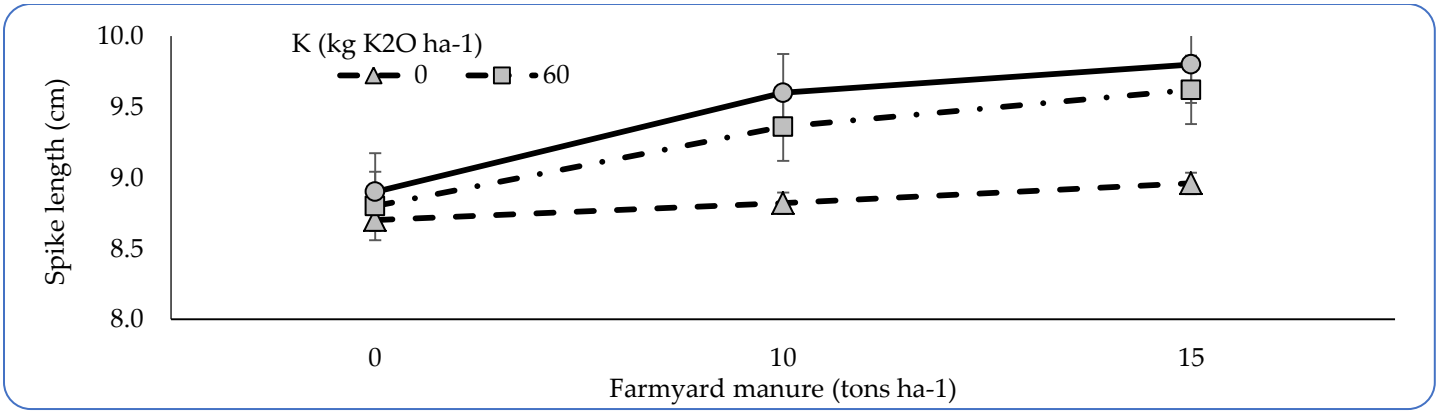
spike length which was noted in the control group (8.82 cm) where zero potassium fertilizer was applied Furthermore, when farmyard manure was combined with a rate of potassium fertilizer90 kg K_2O ha^{-1}, the wheat plants exhibited the maximum spike length of 9.80 cm. In contrast, the control group had the lowest spike length, measuring 8.70 cm. These results indicate the length of the wheat plants' spikes was significantly affected by the interaction between farmyard waste and potassium fertilizer.



Parameters	Mean of squares	F value	LSD @ 0.05
FYM	1.37607	58.44**	0.1991
K-rates	1.19657	66.58**	0.1366
FYM× K-rates	0.11785	5.87**	0.2756
** Significant at 1% level			

Figure 2. Wheat tillers' responses to potassium and levels of farmyard manure. Mean of squares, significant F values, and LSD for the number of tillers.



FYM	Mean of squares	F value	LSD @ 0.05
K-rates	1.03542	1.46 NS	1.0995
FYM× K-rates	0.87707	2.18 NS	0.6528
FYM	0.10778	0.26 NS	1.4253
NS Non-significant			

Figure 3. Wheat spike length as a function of potassium and farmyard waste rates. Squared mean, significant F-values, and LSD for spike length.

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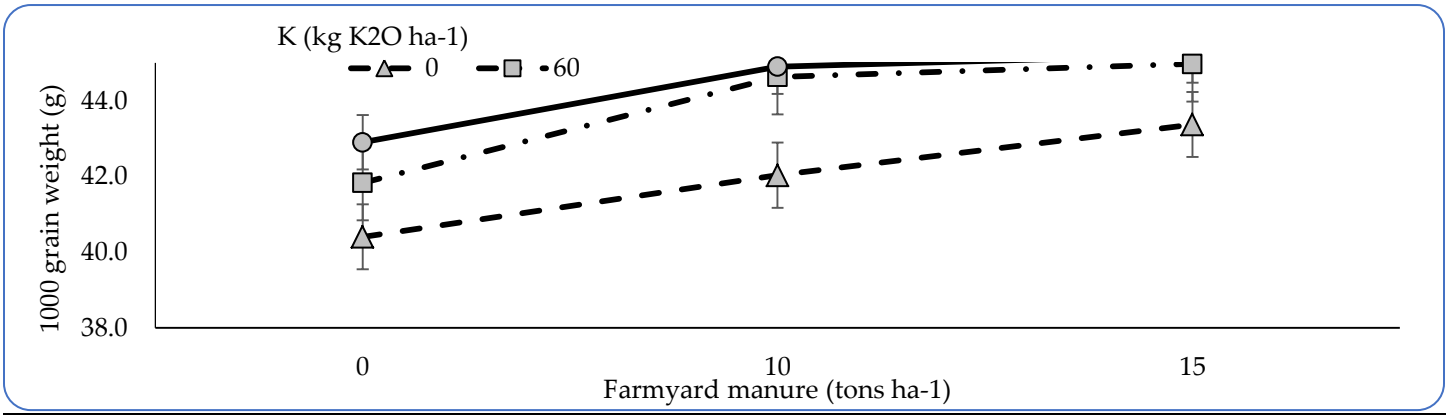
Seed index (1000 grains weight)

The seed index of wheat exhibited an increase, rising from 40.73 g in the control group to 43.52 g with the application of 15.00 tons ha^{-1} of Farmyard Manure (FYM). Similarly, the weight of 1000 grains displayed a proportional rise when combined with potassium (K) fertilizer. The values ascended from 41.92 g in the control group without K fertilizer to 42.82 g at 60.00 kg K_2O ha^{-1} and 43.32 g at 90.00 kg K_2O ha^{-1}. When FYM was paired with K fertilizer, notable distinctions in seed index were evident. The seed index increased from 41.42 g in the control group to 44.23 g when the highest rates of FYM (15.00 tonnes ha^{-1}) and K (90.00 kg K_2O ha^{-1}) were applied. In statistical terms, the application of 10.00 tonnes ha^{-1} of FYM with 90.00 kg K_2O ha^{-1} (43.93 g) and 15.00 tonnes ha^{-1} of FYM with 60.00 kg K_2O ha^{-1} (43.96 g) showed similar seed index performance. These processes statistically matched the acquired seed index by employing 15.00 tonnes ha^{-1} of FYM and 90.00 kg K_2O ha^{-1} (44.23 g).



Parameters	Mean of squares	F value	LSD @ 0.05
FYM	18.3025	490.68**	0.2594
K-rates	13.3383	191.61**	0.2805
FYM× K-rates	0.4478	6.02**	0.4712
** Significant at 1% level			

Figure 4. shows the impact of potassium and farmyard waste rates on wheat seed weight (1000 grains). Mean of squares, significant F values, and LSD for the seed index.

Grain yield

The high grains yield of wheat (3144 kg ha^{-1}) was observed when FYM was done with a rate of 15.00 tonnes ha^{-1}, preceded by 10.00 tons ha^{-1} (3192 kg ha^{-1}), while the control group without FYM had grains yield of 2972 kg ha^{-1}. Similarly, utilization of K fertilizer also led to an improvement in grain yield. The grain yield increased from 2962 kg ha^{-1} in the control group to 3116 kg ha^{-1} at 60.00 kg K_2O ha^{-1} and 3145 kg ha^{-1} at 90.00 kg K_2O ha^{-1}.The findings showed that adding FYM and K fertilizer resulted in substantial variations in grain production. The greatest grain yield (3228 kg ha^{-1}) was observed when FYM at a rate of 15.00 tons ha^{-1} was combined with K at a rate of 90.00 kg K_2O ha^{-1}. However, applying FYM at a rate of 10.00 tons ha^{-1} in combination with 90.00 kg K_2O ha^{-1} (3194 kg ha^{-1}) and applying 15.00 tons ha^{-1} of FYM with 60.00 kg K_2O ha^{-1} (3197 kg ha^{-1}) resulted in grain yields per hectare of land that were statistically comparable.

Straw yield

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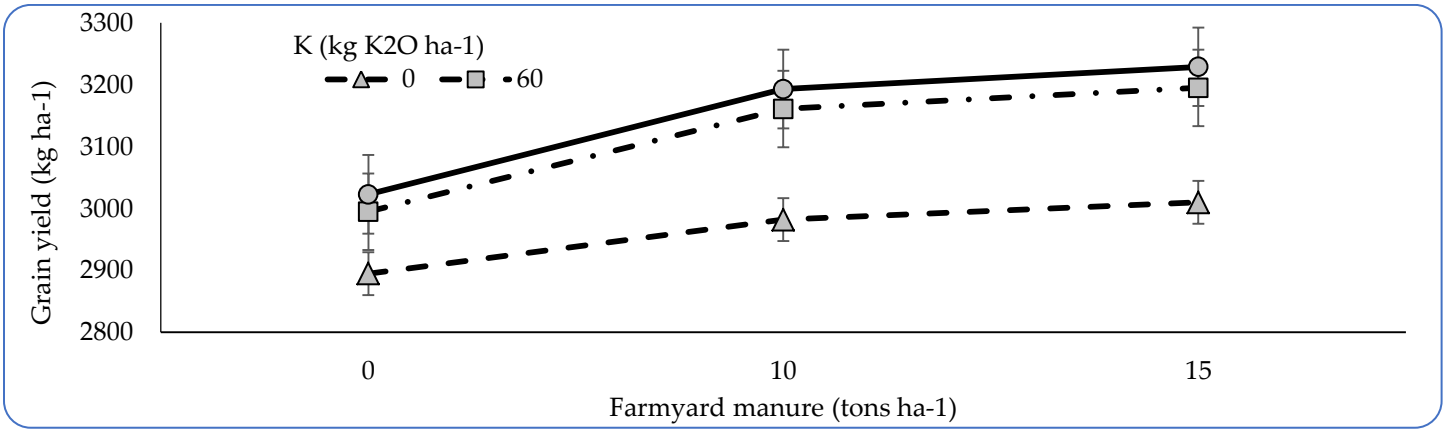
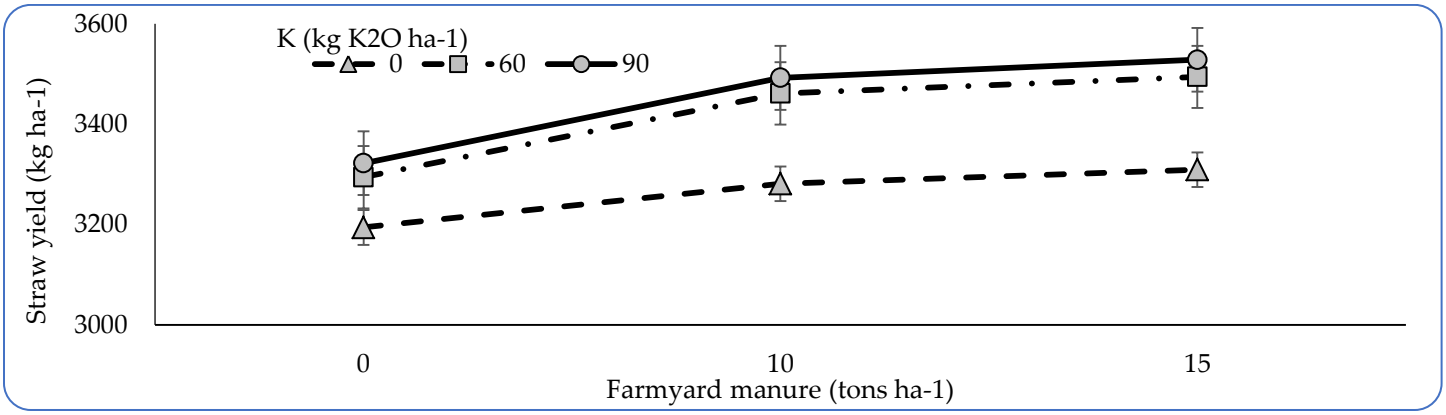
The straw yield of wheat showed an increase from 3191 kg ha^{-1}in the control group, a significant amount of 3527 kg ha^{-1} when FYM at a rate of 15.00 tons ha^{-1} was combined with K fertilizer at a rate of 90.00 kg K_2O ha^{-1}. However, when the FYM rate was reduced to 10.00 tons ha^{-1} with 90.00 kg K_2O ha^{-1} (3493 kg ha^{-1}) or the potassium fertilizer rate was reduced to 60.00 kg K_2O ha^{-1} with 15.00 tons ha^{-1} of FYM (3491 kg ha^{-1}), there was no significant influence on the straw yield, and these treatments were just as effective as the most powerful ones. The minimum straw yield (3271 kg ha^{-1}) was noticed in the control group without FYM but with N, P application.



Parameters	Mean of squares	F value	LSD @ 0.05
FYM	76697.6	687.67**	12.813
K-rates	89693.4	165.02**	21.874
FYM× K-rates	2401.1	5.46**	32.369
** Significant at 1% level			

Figure 5. shows how potassium and farmyard manure rates affect wheat grain output. Mean of squares, F values with significant and LSD for grain yield.



Parameters	Mean of squares	F value	LSD @ 0.05
FYM	76491.5	682.12**	12.841
K-rates	89632.7	168.09**	22.647
FYM× K-rates	2414.8	5.57**	34.084
** Significant at 1% level			

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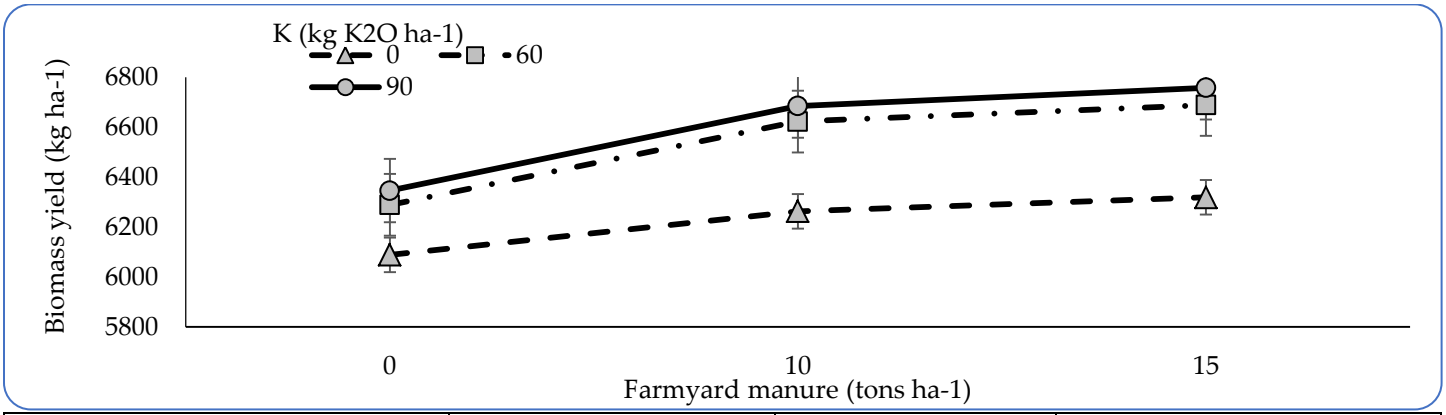
Figure 6. shows how potassium and farmyard manure rates affect the amount of wheat straw produced. Squared mean, significant F values, and LSD for straw yield.

The straw yield increased to 3411 kg ha^{-1}using the programmed of 10 tons ha^{-1} of FYM and further increased to 3443 kg $ha^{-1}$when used in conjunction with 15 tons ha^{-1} of farmyard manure. Similar trends were observed with the application of potassium fertilizer. The highest straw yield (3447 kg ha-1) was attained with an application of 90 kg K2O ha-1, followed by 60.00 kg K2O ha-1 (3416 kg ha-1), while the lowest straw yield (3261 kg ha-1) was noted in the control group. These findings underscore the noteworthy influence of combining Farmyard Manure (FYM) and potassium through fertilization on the production of straw from wheat plants.

Biomass yield

Increasing the application rate of farmyard manure resulted in an increase in biomass yield. 15 tonnes of FYMha^{-1} will be applied. Resulted in the height biomass yield of 6588 kg ha^{-1}, while the high biomass yield of 6241 kg ha^{-1}, and was noted in the NP (no farmyard manure) application. Similar trends were observed with the application of potassium. The biomass yield was highest (6223 kg ha^{-1}) when 90 kg K_2O ha^{-1} was applied. When farmyard manure and potassium fertilizer were mixed, the analysis of means indicated extremely significant changes in biomass yield. The production of biomass increased from 6089 kg ha^{-1} in the N, P plots to 6758 kg ha^{-1} when the height rates of FYM (15.00 tons) and potassium (90.00 kg K_2O) were applied in one hectare. However, reducing the farmyard manure rate from 15 to 10 tons ha^{-1}, or reducing the potassium rate from 90 to 60 kg K_2O ha^{-1}, resulted in statistically similar biomass yields when combined with 90 kg K_2O ha^{-1} or 15 tons ha^{-1} of FYM, respectively.



Parameters	Mean of squares	F value	LSD @ 0.05
FYM	306383	684.63**	25.648
K-rates	358654	165.57**	46.517
FYM× K-rates	9637	5.51**	71.446
** Significant at 1% level			

Figure 7. shows how potassium and farmyard manure rates affect wheat biomass output. Mean of squares, F values with significance and LSD for biomass yield.

Discussion

The application of fertilizer-N had a significant effect on the number of tillers, both effective and non-effective, over the course of two study years. On the other hand, the application of fertilizer-K did not have any impact on the yield-related characteristics of

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wheat. The total number of tillers increased with increasing N application rates, regardless of the level of K rate, but reached its peak at 120 kg N ha^{-1}. This suggests that N plays a crucial role in cell division, elongation, and overall vegetative growth, while K promotes vigorous plant growth through efficient photosynthesis (Chauhan *et al.*, 2020). Previous studies have also reported the individual effects of fertilizer-N and K on the number of tillers in wheat (Sharma *et al.*, 2022). The combined application of fertilizer-N and K resulted in increased tiller production. The number of effective tillers is important as it determines the number of spikes a plant can generate, which ultimately contributes to grain production (Kumar *et al.*, 2021). The need for high wheat yields is influenced by population growth and development, particularly in terms of increasing the number of tillers per unit area (Godebo *et al.*, 2021). The application of fertilizer-K was observed to regulate N metabolism, leading to increased N absorption by the plant (Patel *et al.*, 2021). Therefore, when fertilizer-N and K are applied together, they promote vegetative growth and result in an increased number of fertile tillers per unit area. The soil analysis report revealed that the organic carbon (OC) and total nitrogen (TN) levels were found to be low. Additionally, it indicated the possibility of potassium (K) deficiency induced by magnesium (Mg), which can be attributed to inadequate soil fertility management practices. Therefore, it is advisable to use fertilizers containing nitrogen (N) and potassium (K) to meet the requirements of the wheat crop effectively (Toppo *et al.*, 2023). The number of days it took for the plants to reach physiological maturity was significantly influenced by the interaction between nitrogen (N) and potassium (K) fertilizers. The longest duration was observed when 69 kg N ha^{-1} was applied without K fertilizer. However, the 69 kg N ha^{-1} treatment was statistically similar to the 30 and 60 kg K ha^{-1} treatments. On the contrary, plots that were not fertilized followed by the application of K fertilizer without N fertilizer resulted in a shortened time to reach physiological maturity (Singh *et al.*, 2023).The height of wheat plants was significantly affected by the combined effects of nitrogen (N) and potassium (K) rates. The tallest plant height, measuring 90.57 cm, was achieved when 69 kg of N ha^{-1} was combined with 30 kg of K ha^{-1}. Close behind was a plant height of 84.18 cm, obtained when the same N rate was paired with 60 kg of K ha^{-1}. On the other hand, the shortest plant height of 45.71 cm was observed in unfertilized plots. These findings further illustrate that increasing N rates in combination with K, up to 30 kg ha^{-1}, positively enhanced the height of wheat plants (Bashir *et al.*, 2023). The number of tillers per unit area was greatly influenced by the combined effects of nitrogen (N) and potassium (K) rates. The highest count of total tillers (595.00) was observed when 69 kg $Nha^{-1}$and 30 kg K ha^{-1} were applied, closely followed by the combination of 46 kg N ha^{-1} and the same K rate (548.33). Conversely, the lowest count of total tillers (205.33) was recorded in plots where no fertilization was applied (Ding *et al.*, 2023). The findings indicate that the grain yield was significantly influenced by the interplay between nitrogen (N) and potassium (K) fertilizers. The impact of different combinations of N and K rates on grain yield ranged from 1041 to 4392 kg ha^{-1}. It was observed that all plots that received fertilization had higher grain yield compared to unfertilized plots. Additionally, the grain yield showed a tendency to increase with higher N rates up to 46 kg ha^{-1}, but thereafter declined for all levels of K rates (Xing *et al.*, 2023). The outcomes derived from the combined effects the high grains yield of wheat (3228 kg ha^{-1}) was observed when FYM was done with a rate of 15.00 tonnes ha^{-1}demonstrated a significant impact on the grain yield of wheat, resulting in a corresponding increase in net benefits. While the lowest applying FYM at a rate of 10.00 tons ha^{-1} in combination with 90.00 kg K_2O ha^{-1} (3194 kg ha^{-1}) was observed in the unfertilized treatment.

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Conclusion

Application of potassium with farmyard manure improved the growth, yield and yield contributing parameters and potassium uptake as compared to solo application of each. Increasing the rate of potassium from 60 to 90 kg K_2O ha^{-1} and farmyard manure from 10 to 15 tons ha^{-1} did not produce and significant increase in wheat yield and potassium uptake. The potassium fertilizer use efficiency for grain yield was also highest and equal, when 60 kg K_2O ha^{-1} was coupled with either 10- or 15-tons farmyard manure farmers are recommended this rate for getting better wheat production. On the basis of these results, 60 kg K_2O ha^{-1} with 10 tons of farmyard manure was beneficial.

Conflict of Interest

The authors have not declared any conflict of interest.

Authors Contributions

All the authors contributed equally in the manuscript.

References

Abid, M., S. Ali, L. K. Qi, R. Zahoor, Z. Tian, D. Jiang, J. L. Snider and T. Dai. 2018. Physiological and biochemical changes during drought and recovery periods at tillering and jointing stages in wheat (*Triticum aestivum* L.). Scientific Reports, 8: 4615.

Adisa, I. O., V. L. R. Pullagurala, J. R. Peralta-Videa, C. O. Dimkpa, W. H. Elmer, J. L. Gardea-Torresdey and J. C. White. 2019. Recent advances in nano-enabled fertilizers and pesticides: a critical review of mechanisms of action. Environmental Science: Nano, 6: 2002-30.

Anjum, Z., S. Hayat, M. U. Ghazanfar, S. Ahmad, M. Adnan and I. Hussian. 2020. Does seed priming with *Trichoderma* isolates have any impact on germination and seedling vigor of wheat. International Journal of Botany Studies, 5: 65-68.

Bashir, A., Q. U. Khan, A. Alem, A. A. Hendi, U. Zaman, S. U. Khan, K. u. Rehman, A. A. Khan, I. Ullah and Y. Anwar. 2023. Zinc and potassium fertilizer synergizes plant nutrient availability and affects growth, yield, and quality of wheat genotypes. Plants, 12: 2241.

Bhatt, M. K., R. Labanya and H. C. Joshi. 2019. Influence of long-term chemical fertilizers and organic manures on soil fertility-A review. Universal Journal of Agricultural Research, 7: 177-88.

Chauhan, N., N. Sankhyan, R. Sharma, J. Singh and Gourav. 2020. Effect of long-term application of inorganic fertilizers, farm yard manure and lime on wheat (*Triticum aestivum* L.) productivity, quality and nutrient content in an acid alfisol. Journal of Plant Nutrition, 43: 2569-78.

Chen, H., A. Deng, W. Zhang, W. Li, Y. Qiao, T. Yang, C. Zheng, C. Cao and F. Chen. 2018. Long-term inorganic plus organic fertilization increases yield and yield stability of winter wheat. The Crop Journal, 6: 589-99.

Ding, Y.-G., X.-B. Zhang, M. Quan, F.-J. Li, R.-R. Tao, Z. Min, C.-Y. Li, X.-K. Zhu, W.-S.

https://doi.org/10.55627/Javs.03.1.0389

Guo and J.-F. Ding. 2023. Tiller fertility is critical for improving grain yield, photosynthesis, and nitrogen efficiency in wheat. Journal of Integrative Agriculture, 22: 2054-66.

Godebo, T., F. Laekemariam and G. Loha. 2021. Nutrient uptake, use efficiency and productivity of bread wheat (*Triticum aestivum* L.) as affected by nitrogen and potassium fertilizer in Keddida Gamela Woreda, Southern Ethiopia. Environmental Systems Research, 10: 1-16.

Kumar, A., J. Rabha and D. K. Jha. 2021. Antagonistic activity of lipopeptide-biosurfactant producing *Bacillus subtilis* AKP, against *Colletotrichum capsici*, the causal organism of anthracnose disease of chilli. Biocatalysis and Agricultural Biotechnology, 36: 102133.

Manzoor, M. Shafi, A. Sohail, S. Ali, S. Anwar and S. Fahad. 2019. Fertilizer management for improving water use efficiency in winter cereals in semiarid region of northwest, Pakistan. Russian Agricultural Sciences, 45: 550-60.

Patel, S. H., M. Viradiya and B. J. Prajapati. 2021. Effect of potassium and potassium mobilizing bacteria (KMB) with and without FYM on yield of wheat (*Triticum aestivum* L.). Journal of Pharmacognosy and Phytochemistry, 10: 1615-20.

Riaz, A., M. Aziz, A. Ghaffar, W. Ahmed, K. Mubeen and M. Usman. 2022. Evaluation of differnt sowing methods for enhancing productivity and water use efficiency of wheat under limited water condition. International Journal of Agricultural Extension, 10: 23-31.

Sharma, S., G. Kaur, P. Singh, S. Alamri, R. Kumar and M. H. Siddiqui. 2022. Nitrogen and potassium application effects on productivity, profitability and nutrient use efficiency of irrigated wheat (*Triticum aestivum* L.). PLoS One, 17: e0264210.

Singh, R., S. K. Sawatzky, M. Thomas, S. Akin, H. Zhang, W. Raun and D. B. Arnall. 2023. Nitrogen, phosphorus, and potassium uptake in rain-fed corn as affected by NPK fertilization. Agronomy, 13: 1913.

Toppo, M., A. K. Sinha, A. K. Upadhay and P. Mahapatra. 2023. Effect of long-term application of inorganic fertilizers, organic manure, and lime on different forms of potassium in soil under maize-wheat cropping system. International Journal of Plant and Soil Science, 35: 469-80.

Townsend, T., D. Sparkes, S. Ramsden, N. Glithero and P. Wilson. 2018. Wheat straw availability for bioenergy in England. Energy Policy, 122: 349-57.

Wahid, F., M. Sharif, M. A. Khan, A. Ali, A. M. Khattak and A. R. Saljoqi. 2015. Addition of rock phosphate to different organic fertilizers influences phosphorus uptake and wheat yield. Ciência e Técnica, 30: 91-100.

Wang, X., Z. Jia, L. Liang, B. Yang, R. Ding, J. Nie and J. Wang. 2016. Impacts of manure application on soil environment, rainfall use efficiency and crop biomass under dryland farming. Scientific Reports, 6: 20994.

Xing, G., J. Ma, X. Liu, B. Lei, G. Wang, S. Hou and Y. Han. 2023. Influence of different nitrogen, phosphorus, and potassium fertilizer ratios on the agronomic and quality traits of foxtail millet. Agronomy, 13: 2005.

Yahya, K. E., Z. Jia, W. Luo, H. YuanChun and M. A. Ame. 2022. Enhancing salt leaching

https://doi.org/10.55627/Javs.03.1.0389

efficiency of saline-sodic coastal soil by rice straw and gypsum amendments in Jiangsu coastal area. Ain Shams Engineering Journal, 13: 101721.

https://doi.org/10.55627/Javs.03.1.0389