Response of Wheat to Varying Levels of Nitrogen and Phosphorus Under Semi-Arid Conditions of Rajasthan

Vikash[1], G.R. Chaudhary[2], EVD Sastry[3], Ajeet Singh[4], Yasir Ajeej Tamboli[5], Mukesh Kumar Yadav[6], Rahul[7], Neha Bharti[8]

[1,7,8]M.Sc. Scholar, Department of Agronomy, School of Agricultural Sciences Jaipur National University, Jaipur, Rajasthan, India.
[2,3]Professor, Department of Agronomy, School of Agricultural Sciences Jaipur National University, Jaipur, Rajasthan, India.
[4,5,6]Assistant Professor, Department of Agronomy, School of Agricultural Sciences Jaipur National University, Jaipur, Rajasthan, India.

ABSTRACT
A field experiment was conducted during Rabi 2024-25 at the Agricultural Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, to study the response of wheat (RJ 4037) to varying levels of nitrogen and phosphorus under semi-arid conditions of Rajasthan. The experiment was laid out in factorial randomized block design with three replications, consisting of four nitrogen levels (0, 60, 120, 180 kg/ha) and three phosphorus levels (0, 20, 40 kg P_2O_5/ha). Results revealed that the application of 180 kg N/ha and 40 kg P_2O_5/ha significantly improved growth, yield attributes, grain yield, straw yield, and protein content over lower levels. The highest grain yield (4650 kg/ha) and straw yield (6150.5 kg/ha) were obtained under 180 kg N + 40 kg P_2O_5/ha. Protein content in grain increased to 13.43% under 40 kg P_2O_5/ha, while economics showed maximum gross return (₹1,23,141/ha) and net return (₹88,348/ha) with a B:C ratio of 2.67 under 180 kg N + 40 kg P_2O_5/ha. Thus, balanced application of nitrogen and phosphorus is essential for enhancing wheat productivity, profitability, and soil fertility under semi-arid conditions.

Keywords: Wheat, Nitrogen, Phosphorus, Yield, Protein, Economics, Semi-arid conditions

1. Introduction:

Wheat (Triticum aestivum L.) is one of the most important staple food crops of India, contributing significantly to national food security. India cultivates wheat on about 30 million hectares with a production exceeding 100 million tonnes (FAO, 2023). Semi-arid regions of Rajasthan, where wheat is extensively grown, are characterized by sandy soils, low organic matter, and nutrient deficiencies that constrain productivity (Singh et al., 2020). Nutrient management, particularly nitrogen and phosphorus fertilization, is therefore crucial to sustain and enhance wheat yields.
Nitrogen is a primary nutrient for cereals, as it forms the basis of chlorophyll, proteins, and nucleic acids. Adequate nitrogen fertilization increases tillering, leaf area, photosynthetic efficiency, and dry matter

accumulation, which ultimately enhances yield (Ullah et al., 2018). Phosphorus, the second key nutrient, plays an important role in root development, energy transfer, and reproductive growth. It enhances spike length, grain setting, and kernel development. Phosphorus deficiency is widespread in Indian soils, especially in sandy and semi-arid regions, due to fixation and low availability (Ali et al., 2020; Grant et al., 2001).

The wheat productivity of the country is low as compared to world average. Such mismatch in the yield may be attributed to various biotic and abiotic stress constraints augmented by environmental factors which adversely affect growth, metabolism and yield. Among various abiotic factors phosphorus and nitrogen dose is the foremost factor that possess highest regulation potential to wheat yield which can be made possible by determining the optimal phosphorus and nitrogen doses for Wheat. The optimal dose of NP not only increases the grain yield but also quality, straw yield and net returns. Poor supply of NP could results in decrease wheat yield up to 18–73 per cent. Phosphorus and nitrogen is the most important input in achieving a variety's hereditary potential in terms of final grain output. (Priyanshi *et al.,* 2025).

Nitrogen and phosphorus are the major factors in achieving higher yield because both the nutrients promote growth of plants. Nitrogen is one of the basic elements required for obtaining higher wheat yield. It is largely needed in the synthesis of protein, chlorophyll and other vital compounds which are attributed to all physiological and biochemical processes of plants. The response of yield to N & P fertilization varies according to location, climate, crops and their varieties as well as type and characteristics of the soil, rate, time of fertilizer application and its placement (Markad, 2024).

Balanced application of nitrogen and phosphorus not only improves yield attributes and productivity but also influences quality parameters such as protein content and nutrient uptake (Shende et al., 2020; Sagar et al., 2018). However, limited research has been carried out on the interactive effects of nitrogen and phosphorus under the semi-arid conditions of Rajasthan. This region, with poor soil fertility and climatic constraints, requires site-specific fertilizer recommendations for maximizing yield and profitability. Therefore, the present investigation was undertaken with the following objectives:

1. To evaluate yield response to varying phosphorus and nitrogen doses in wheat.
2. To determine the optimal phosphorus and nitrogen doses for maximum yield of wheat.
3. To evaluate the economics of the treatments.

2. MATERIALS AND METHODS:

The experiment was conducted during Rabi 2024-25 at the Agricultural Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan. The soil was sandy in texture with pH 7.58, organic carbon 0.43%, and low in available nitrogen and phosphorus. The experiment was laid out in factorial randomized block design (FRBD) with three replications, consisting of four nitrogen levels (0, 60, 120, 180 kg N/ha) and three phosphorus levels (0, 20, 40 kg P_2O_5/ha), making 12 treatment combinations. Wheat variety 'RJ 4037' was sown @ 100 kg/ha with spacing of 22.5 cm x 5 cm. Standard agronomic practices including seven irrigations were followed uniformly. Observations were recorded on growth, yield attributes, yield, quality, post-harvest soil fertility, and economics. Data were analyzed statistically using ANOVA for factorial RBD.

3. RESULT AND DISSCUSSION:

3.1 Growth parameters

3.1.1 Plant height (cm)

At harvest the highest plant height (91.71 cm) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (91.41 cm) recorded highest plant height in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. These findings are supported by (Li *et al.,* 2020) and (Mussarat *et al.,* 2021).

3.1.2 Number of effective tillers per meter row length

Highest number of effective tillers per meter row length (107.75) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (107.00) recorded highest number of effective tillers per meter row length in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. Similar results are given by (Leonte *et al.,* 2021) and (Marques *et al.,* 2024).

3.2 Yield parameters

3.2.1 Spike length (cm)

At harvest highest spike length (9.12 cm) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (9.10 cm) recorded highest spike length in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. Similar findings are shown by (Xiao *et al.,* 2021) and (Khan *et al.,* 2021).

3.2.2 Number of grains per spike

At harvest highest number of grains per spike (47.00) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (46.75) recorded highest number of grains per spike in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. Similar results are given by (Rafiullah *et al.,* 2020) and Sharma *et al.,* 2022).

3.2.3 Grain Yield (kg ha^{-1})

At harvest highest grain yield (4650 kg ha^{-1}) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (4600kg ha^{-1}) recorded highest grain yield in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. Similar findings are shown by (Stefanova-Dobreva *et al.,* 2022) (Khan *et al.,* 2021).

3.2.4 Straw Yield (kg ha^{-1})

At harvest highest straw yield (6150.50 kg ha^{-1}) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (6033kg ha^{-1}) recorded highest straw yield in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. Similar results are given by (Leonte *et al.,* 2021) and (Maurya *et al.,* 2024).

3.3 Quality parameters

3.3.1 Protein content seed (%)

At harvest highest protein content seed (13.43 %) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (12.53 %) recorded highest protein content seed in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. These findings are supported by (Zhang *et al.,* 2020) and (Marques *et al.,* 2024).

3.3.2 Protein content straw (%)

At harvest highest protein content straw (4.98 %) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (4.51 %^{1}) recorded highest protein content straw in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. Similar findings are shown by (Xiao *et al.,* 2021) and (Chen *et al.,* 2021).

3.3.3 Protein Yield Seed (kg ha⁻¹)

At harvest highest protein yield seed (548.31 kg ha^{-1}) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (478.72 kg ha^{-1}) recorded highest protein yield seed in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. Similar results are given by (Rafiullah *et al.,* 2020) and (Mussarat *et al.,* 2021).

3.3.4 Protein Yield Straw (kg ha⁻¹)

At harvest highest protein yield straw (270.20 kg ha^{-1}) was reported with application of P_2O_5 (40 kg ha^{-1})) which was significantly superior over all others. However, application of Nitrogen (180 kg h^{-1}) (243.31 kg ha^{-1}) recorded highest protein yield straw in nitrogen levels. Thus, the combination of Nitrogen (180 kg h^{-1}) + P_2O_5 (40 kg ha^{-1}) found to be the best among all treatments. These findings are supported by (Li *et al.,* 2020) and (Chen *et al.,* 2021).

3.3.5 Available Nitrogen and Phosphorus in soil

Post-harvest soil available nitrogen improved from 170.5 to 202.5 kg ha^{-1} with increasing fertilizer application. The enhancement reflects better nutrient cycling and residual N retention due to improved microbial activity. Available phosphorus content also increased from 13.3 to 15.95 kg ha^{-1} at 180 kg N + 40 kg P_2O_5 ha^{-1}. The rise in available P may be due to reduced fixation and enhanced solubilization under better root growth (Choudhary et al., 2021)

3.4 Economics

Economic evaluation revealed that 180 kg N + 40 kg P_2O_5 ha^{-1} recorded the highest gross return (₹1,23,141 ha^{-1}), net return (₹88,348 ha^{-1}), and B:C ratio (2.67). Although input cost increased, yield gains ensured greater profitability. These findings agree with Sagar et al. (2018) and Verma et al. (2019).

4. CONCLUSION:

The study concluded that the combined application of 180 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1} significantly improved growth, yield, protein content, and profitability of wheat under semi-arid conditions of Rajasthan. This treatment achieved the highest grain yield (4650 kg ha^{-1}), protein content (13.43%), and B:C ratio (2.67). Therefore, balanced nitrogen and phosphorus application can be recommended for sustainable wheat production and soil fertility maintenance.

REFERENCES:

1. Ali, M. et al. (2020). *Phosphorus fertilization and its residual effect on soil fertility.* Soil Science Research, 12(1), 33–41.
2. Chen, Y., Li, S., Liu, N., He, H., Cao, X., Lv, C., & Dai, J. (2021). Effects of different types of microbial inoculants on available nitrogen and phosphorus, soil microbial community, and wheat growth in high-P soil. *Environmental Science and Pollution Research*, *28*, 23036-23047.
3. Choudhary, R. et al. (2021). *Integrated nutrient management for sustainable wheat production in Rajasthan.* Indian Journal of Agricultural Sciences, 91(6), 921–927.
4. FAO (2023). *FAOSTAT statistical database.* Food and Agriculture Organization of the United Nations, Rome.
5. Grant, C.A. et al. (2001). *Importance of phosphorus in crop production.* Canadian Journal of Plant Science, 81(2), 211–224.
6. Khan, A. A., Khan, I., Jan, M. F., Liaqat, W., Muhammad, A., & Anwar, S. (2021). Phenology, growth, yield and nitrogen uptake of wheat in response to nitrogen, potassium and their application methods: effect of nitrogen and potassium on growth of wheat. *Biological Sciences-PJSIR*, *64*(2), 142-159.
7. Leonte, A., Agapie, A., Pintilie, P. L., DRUTU, A. C., Amarghioalei, G., & ESANU, S. (2021). Research regarding the influence of nitrogen and phosphorus fertilizers on winter wheat, in the pedoclimatic conditions in Central of Moldavia. *Life Science and Sustainable Development*, *2*(2), 52-57.
8. Li, Y., Tremblay, J., Bainard, L. D., Cade‐Menun, B., & Hamel, C. (2020). Long‐term effects of nitrogen and phosphorus fertilization on soil microbial community structure and function under continuous wheat production. *Environmental Microbiology*, *22*(3), 1066-1088.
9. Markad, A. (2024). Role of nitrogen in wheat production system and nitrogen for improving wheat yield and quality: A review. Journal of Experimental Agriculture International, 46(7), 599-609. https://doi.org/10.9734/jeai/2024/v46i72613
10. Marques da Silva, S. S., Faizullah, L., Guignard, M. S., Orcen, N., Ruban, A. V., Rudall, P. J., ... & Leitch, A. R. (2024). Nitrogen and phosphorus interactions at a 21 nitrogen: 1 phosphorus Redfield‐like ratio impact growth and seed yield in wheat (Triticum aestivum L.). *Food and Energy Security*, *13*(4), e564.
11. Maurya, D. K., & Kumar, M. (2024). Effect of Nitrogen and Phosphorus Fertilization on the Growth and Yield of Wheat (Triticum aestivum L.). *Int. J. Environ. Clim. Change*, *14*(1), 552-557.
12. Mussarat, M., Shair, M., Muhammad, D., Mian, I. A., Khan, S., Adnan, M., ... & Khan, F. (2021). Accentuating the role of nitrogen to phosphorus ratio on the growth and yield of wheat crop. *Sustainability*, *13*(4), 2253.
13. Priyanshi, Husain, K., Singh, V., Singh, A., Chaurasiya, S., & Kumar, S. (2025). Effect of nano fertilizer on yield and economics of wheat (Triticum aestivum L.). International Journal of Botany Studies, 9(5), 7-13. https://doi.org/10.33545/26174693.2025.v9.i5a.4288
14. Rafiullah, Khan, M. J., Muhammad, D., Fahad, S., Adnan, M., Wahid, F., ... & Siddiqui, M. H. (2020). Phosphorus nutrient management through synchronization of application methods and rates in wheat and maize crops. *Plants*, *9*(10), 1389.
15. Sagar, V. et al. (2018). *Response of wheat to nitrogen and phosphorus application under arid conditions.* International Journal of Agricultural Sciences, 10(7), 5564–5568.

16. Shende, S. et al. (2020). *Effect of nitrogen on wheat yield and yield attributes.* International Journal of Current Microbiology and Applied Sciences, 9(2), 1999–2008.Sharma, S., Kaur, G., Singh, P., Alamri, S., Kumar, R., & Siddiqui, M. H. (2022). Nitrogen and potassium application effects on productivity, profitability and nutrient use efficiency of irrigated wheat (Triticum aestivum L.). *Plos one*, *17*(5), e0264210.
17. Singh, P. et al. (2020). *Fertilizer management in wheat under semi-arid conditions.* Journal of Wheat Research, 12(1), 33–42.
18. Stefanova-Dobreva, S., Muhova, A., & Bonchev, B. (2022). Nitrogen and phosphorus fertilizers affecting the quality and quantity of the durum wheat. *Scientific Papers. Series A. Agronomy*, *65*(1).
19. Ullah, H. et al. (2018). *Nitrogen fertilization improves growth and yield of wheat.* Journal of Crop Science and Biotechnology, 21(3), 261–270.
20. Verma, A. et al. (2019). *Effect of nutrient management on soil fertility and wheat productivity.* Indian Journal of Agronomy, 64(3), 367–373.
21. Xiao, J. X., Zhu, Y. A., Bai, W. L., Liu, Z. Y., Li, T. A. N. G., & Zheng, Y. (2021). Yield performance and optimal nitrogen and phosphorus application rates in wheat and faba bean intercropping. *Journal of Integrative Agriculture*, *20*(11), 3012-3025.
22. Zhang, Q., Song, Y., Wu, Z., Yan, X., Gunina, A., Kuzyakov, Y., & Xiong, Z. (2020). Effects of six-year biochar amendment on soil aggregation, crop growth, and nitrogen and phosphorus use efficiencies in a rice-wheat rotation. *Journal of Cleaner Production*, *242*, 118435.

Table 1. Effect of levels of nitrogen and phosphorus on growth parameters of wheat.

Treatments	Number of effective tillers per meter row length	Plant height (cm)
Nitrogen levels		
0 kg ha^{-1}	81.67	80.72
60 kg ha^{-1}	91.33	85.29
120 kg ha^{-1}	99.33	87.95
180 kg ha^{-1}	107.00	91.41
SEm±	1.73	1.54
CD	5.08	4.51
CV (%)	5.5	5.31
P_2O_5 levels		
0 kg ha^{-1}	73.25	80.16
20 kg ha^{-1}	103.50	89.19
40 kg ha^{-1}	107.75	91.71
SEm±	1.50	1.33
CD	4.40	3.91
CV (%)	5.5	5.31

Table 2 Effect of levels of nitrogen and phosphorus on yield parameters and yield of wheat.

Treatments	Spike Length (cm)	No. of Grains per Spike	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})

Nitrogen levels				
0 kg ha^{-1}	7.70	39.00	4233.33	5673.83
60 kg ha^{-1}	8.37	41.67	4550.00	6048.65
120 kg ha^{-1}	8.73	44.33	4583.33	6060.72
180 kg ha^{-1}	9.10	46.75	4600.00	6033.38
SEm±	0.22	0.77	140.55	201.10
CD	0.65	2.26	486.40	695.93
CV (%)	5.30	5.37	5.42	5.85
P_2O_5 levels				
0 kg ha^{-1}	7.63	37.00	4250	5650
20 kg ha^{-1}	8.88	45.25	4537.5	6037.5
40 kg ha^{-1}	9.12	47.00	4650	6150.5
SEm±	0.19	0.67	140.16	200.83
CD	0.56	1.95	485.05	694.97
CV (%)	5.30	5.37	5.42	5.85

Table 3. Effect of levels of nitrogen and phosphorus on quality parameters of wheat.

Treatments	**Protein Content Seed (%)**	**Protein Content Straw (%)**	**Protein Yield Seed (kg ha^{-1})**	**Protein Yield Straw (kg ha^{-1})**
Nitrogen levels				
0 kg ha^{-1}	10.11	3.61	383.31	201.65
60 kg ha^{-1}	11.80	4.01	423.31	219.98
120 kg ha^{-1}	12.50	4.45	478.31	242.64
180 kg ha^{-1}	12.53	4.51	478.72	243.31
SEm±	0.21	0.08	7.70	3.95
CD	0.62	0.23	22.57	11.57
CV (%)	5.20	5.40	5.04	5.06
P_2O_5 levels				
0 kg ha^{-1}	10.61	4.04	437.49	222.24
20 kg ha^{-1}	12.25	4.26	458.73	232.48
40 kg ha^{-1}	13.43	4.98	548.31	270.20
SEm±	0.18	0.07	6.67	3.42
CD	0.54	0.20	19.55	10.02
CV (%)	5.20	5.40	5.04	5.06

Table 4. Effect of levels of nitrogen and phosphorus on nitrogen content and uptake of wheat.

Treatments	**Available N Before**	**Available N After**	**Available P Before**	**Available P After**
Nitrogen levels				
0 kg /ha	180.20	170.50	14.10	13.00
60 kg /ha	182.30	180.64	15.10	14.50

120 kg /ha	184.00	191.00	16.00	15.40
180 kg /ha	185.50	202.50	16.80	16.10
SEm±	3.85	2.62	3.95	2.65
CD	7.29	8.14	11.57	8.15
CV (%)	5.31	4.67	5.10	4.14
P_2O_5 levels				
0 kg /ha	181.10	180.98	14.00	13.30
20 kg /ha	183.30	186.30	15.90	15.00
40 kg /ha	184.60	191.20	16.60	15.95
SEm±	3.33	4.72	3.42	4.00
CD	9.77	14.49	10.02	12.30
CV (%)	5.31	8.20	5.10	6.16

Table 5. Effect of levels of nitrogen and phosphorus on economics of wheat.

Treatments	Cost of Cultivation (Rs/ha)	Gross Return (Rs/ha)	Net Return (Rs/ha)	B:C Ratio
Nitrogen levels				
0 kg ha^{-1}	32704.12	118827.41	86123.29	2.65
60 kg ha^{-1}	32937.16	118902.09	85964.94	2.62
120 kg ha^{-1}	33170.21	119140.39	85970.18	2.61
180 kg ha^{-1}	33403.24	121751.28	88348.04	2.67
SEm±	297.90	2213.58	1978.39	0.04
CD	873.78	6492.62	5802.76	0.12
CV (%)	1.71	2.55	2.85	1.93
P_2O_5 levels				
0 kg ha^{-1}	31273.53	113883.67	82610.15	2.66
20 kg ha^{-1}	33053.68	121940.62	88886.94	2.70
40 kg ha^{-1}	34833.84	123141.59	88307.75	2.55
SEm±	297.90	2213.58	1978.39	0.04
CD	873.78	6492.62	5802.76	0.12
CV (%)	1.71	2.55	2.85	1.93