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WHEAT YIELD RESPONSE TO POTASSIUM FERTILIZATION UNDER DIFFERENT NITROGEN AND PHOSPHORUS REGIMES

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ABSTRACT

This study evaluated the effect of potassium fertilization applied under different nitrogen and phosphorus regimes on the grain yield of wheat grown after pea under rainfed conditions at the S.C.D.A 2022-2026. The experiment comprised 16 treatments resulting from the combination of four N-P fertilization regimes (N0P0, N60P0, N60P80, and N120P80) with four K fertilization rates (K0, K40, K80, and K120). Grain yield was determined annually from 2022 to 2026. The topsoil had low inherent fertility and contained 12.5 mg available K_2O per 100 g soil. Meteorological data indicated precipitation deficits in the 2021-2022, 2023-2024, and 2024-2025 agricultural years, whereas 2022-2023 and 2025-2026 received precipitation above the reference average. The unfertilized control produced a mean grain yield of 1.80 t ha^{-1}. The main effect of K was positive, although its magnitude depended on the N-P regime. The highest five-year mean grain yield, 6.86 t ha^{-1}, was recorded for N120P80K80; at the highest N-P regime, K40 and K80 produced nearly identical yields, while K120 provided no additional yield benefit. Five-year mean yields were used to characterize the multi-year response. The results support the need for balanced N-P-K fertilization adapted to soil fertility status and year-to-year variability in environmental conditions.

INTRODUCTION

Crop rotation influences soil fertility, nutrient availability, and the fertilization response of the subsequent crop. Grain legumes are of particular interest because of their contribution to nitrogen cycling and resource-use efficiency. Lasisi & Liu (2023) reported beneficial effects of pulse crops on the yield of subsequent cereal crops and on nitrogen and water-use efficiency, while St. Luce et al. (2015) showed that preceding leguminous crops, including pea, can alter nitrogen availability and the nitrogen fertilizer requirement of wheat.

In such rotations, the response of wheat should not be interpreted solely in terms of nitrogen. Potassium is involved in the regulation of cell turgor, stomatal function, assimilate transport, and enzyme activity; consequently, adequate K nutrition contributes both to yield formation and to plant responses to abiotic stress, including water deficit (Zörb et al. 2014). The agronomic response to K also depends on soil properties and the initial level of available potassium (Fontana et al. 2022). Long-term studies have shown that yield responses to N, P, and K vary with the

production environment and nutrient combination, while the co-application of P and K may affect nitrogen-use efficiency (Duncan et al. 2018; Lollato et al. 2019).

Recent results also confirm that a balanced N and K supply can sustain yield and nutrient-uptake efficiency, whereas nutrient imbalance may reduce fertilizer-use efficiency (Zhang et al. 2026). Under the conditions of southwestern Romania, these relationships must be interpreted in conjunction with the agrochemical status of the soil. Regional research has also addressed the agrochemical characterization of soils in Olt County (Dodocioiu et al. 2013), providing a complementary geographical context for studies of soil fertility in southwestern Romania. Dodocioiu & Buzatu (2024) analyzed N, P, and K dynamics in the soil-wheat system. Research on wheat in southwestern Romania has also addressed grain biochemical quality, including total phenolic content and antioxidant activity in whole-grain flours from locally tested wheat lines (Paunescu et al. 2016b).The objective of the present study was to evaluate wheat grain yield response to increasing K rates during 2022-2026 under four N-P fertilization regimes and to determine how the nutrient background and annual environmental conditions modified the magnitude of the yield response.

MATERIAL AND METHODS

The experiment was conducted at the Șimnic-Craiova Agricultural Research and Development Station, where winter wheat (cv. Dropia) was grown after pea. The reddish preluvosol at the Șimnic Agricultural Research and Development Station has previously been characterized by Radu et al. (2019).The experiment comprised 16 fertilization treatments. Plots were 8 m long and 4 m wide, corresponding to an area of 32 m². The factorial design included four N-P fertilization regimes (N0P0, N60P0, N60P80, and N120P80) and four K fertilization rates (K0, K40, K80, and K120). Nitrogen, phosphorus, and potassium fertilizer rates are expressed as kg N ha^{-1}, kg P_2O_5 ha^{-1} and kg K_2O ha^{-1} respectively. The fertilizers used in the experiment were NPK 20-20-20 compound fertilizer, ammonium nitrate containing 33.4 % N, and concentrated superphosphate.

Grain yield was determined annually during 2022-2026 and expressed as t ha^{-1}. Data were analyzed by analysis of variance (ANOVA), and treatment differences were interpreted using least significant difference (LSD) values at the 5%, 1%, and 0.1 % probability levels for factor A (N-P fertilization regime), factor B (K rate), and the AxB and BxA comparisons. For analysis of the entire 2022-2026 period, arithmetic means of the yields obtained over the five years were calculated for each experimental treatment. These means were used to compare the multi-year yield response to the different fertilization combinations, whereas the significance of treatment differences was assessed annually using the LSD values.

The soil at the experimental site was a slightly podzolized reddish-brown soil developed on fine-textured proluvial material. It was slightly acidic (pH 5.8), with 2.03 % humus, 0.090 % total N, 0.102 % total P_2O_5, and 12.5 mg available K_2O per 100 g soil in the plough layer. Base saturation exceeded 75 %, however, the relatively low humus and nutrient contents indicate low inherent soil fertility. The plough layer had a clay-loam texture with 31.9 % clay, while clay content exceeded 40% in the deeper horizons. Field capacity was approximately 24-25 %, the wilting coefficient was 11.1 %, and surface bulk density was approximately 1.40 g cm^{-3}.

Meteorological data for the 2021-2022, 2022-2023, 2023-2024, 2024-2025, and 2025-2026 agricultural years, corresponding to the 2022-2026 harvests, showed pronounced hydrothermal variability (Table 1). In 2021-2022, the mean temperature

was 12.7 °C, 0.3 °C above the 15-year reference mean, while precipitation totaled 508.3 mm, representing a deficit of 155.4 mm. The 2022-2023 agricultural year had above-average precipitation (+116.3 mm), whereas 2023-2024 and 2024-2025 recorded severe deficits of 230.7 and 223.8 mm, respectively. In 2025-2026, the mean temperature was 12.7°C, equal to the multi-year mean, and precipitation totaled 781.0 mm, 141.3 mm above the reference value.

Table 1

Climatic conditions during 2021-2026

Agricultural year	Mean T (°C)	T deviation (°C)	Precipitation (mm)	P deviation (mm)
2021-2022	12.7	+0.3	508.3	-155.4
2022-2023	13.5	+1.1	775.0	+116.3
2023-2024	15.5	+3.1	463.0	-230.7
2024-2025	13.5	+1.0	438.0	-223.8
2025-2026	12.7	0.0	781.0	+141.3

RESULTS AND DISCUSSIONS

Wheat grain yield varied significantly with both the N-P fertilization regime and K rate (Table 2). The five-year mean yield of the unfertilized control (N0P0K0) was 1.80 t ha^{-1}. Increasing the N-P fertilization level markedly increased baseline yield, while the additional response to K differed among nutrient regimes. Among all treatments, the highest five-year mean yield, 6.86 t ha^{-1}, was obtained with N120P80K80. Comparison of the multi-year means summarizes the cumulative yield response of the treatments over the entire 2022-2026 period.

Table 2

Wheat grain yield as affected by N-P fertilization regime and K rate (t ha^{-1})

Treatment / LSD	2022	2023	2024	2025	2026	Mean
N0P0K0	2.13	1.28	2.06	1.90	1.64	1.80
N0P0K40	2.80	2.30	2.81	2.40	1.83	2.43
N0P0K80	2.85	2.74	3.02	2.57	2.15	2.67
N0P0K120	2.96	3.35	3.14	2.67	2.27	2.88
N60P0K0	4.50	3.92	3.73	3.30	4.35	3.96
N60P0K40	4.71	4.56	4.43	3.73	4.98	4.48
N60P0K80	4.77	4.87	4.85	4.08	5.08	4.73
N60P0K120	5.04	5.07	5.11	4.12	5.17	4.90
N60P80K0	6.60	5.51	6.64	4.43	6.28	5.89
N60P80K40	6.83	5.80	6.72	4.52	6.36	6.05
N60P80K80	6.95	6.00	7.00	4.62	6.47	6.21
N60P80K120	7.02	6.03	7.28	4.97	6.49	6.36

N120P80K0	7.37	6.13	7.39	5.10	6.83	6.56
N120P80K40	7.58	6.26	7.56	5.58	7.25	6.85
N120P80K80	7.66	6.47	7.53	5.35	7.31	6.86
N120P80K120	7.70	6.34	7.50	5.32	6.99	6.77
LSD 5% A (N-P)	0.30	0.13	0.36	0.26	0.34	-
LSD 1% A (N-P)	0.43	0.19	0.52	0.37	0.48	-
LSD 0.1% A (N-P)	0.64	0.28	0.77	0.55	0.71	-
LSD 5% B (K)	0.27	0.12	0.33	0.23	0.30	-
LSD 1% B (K)	0.36	0.16	0.44	0.31	0.40	-
LSD 0.1% B (K)	0.48	0.21	0.58	0.41	0.53	-
LSD 5% AxB	0.34	0.28	0.62	0.42	0.69	-
LSD 1% AxB	0.46	0.38	0.85	0.56	0.94	-
LSD 0.1% AxB	0.61	0.51	1.16	0.74	1.27	-
LSD 5% BxA	0.42	0.29	0.58	0.45	0.69	-
LSD 1% BxA	0.59	0.38	0.77	0.61	0.93	-
LSD 0.1% BxA	0.82	0.52	1.02	0.84	1.23	-

Note: LSD = least significant difference; A = N-P fertilization regime; B = K fertilization rate

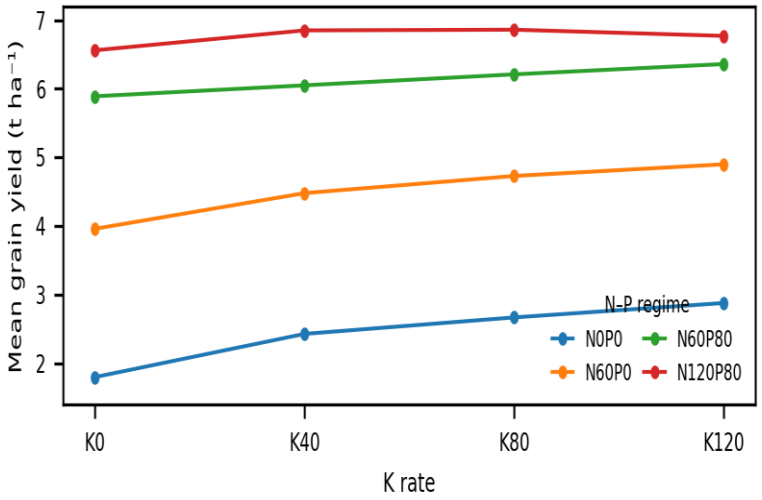


Figure 1. Effect of K rate on five-year mean wheat grain yield under different N-P fertilization regimes, 2022-2026

The N-P fertilization regime exerted a major influence in each year. Factor A means increased from 2.69 to 7.58 t ha^{-1} in 2022, from 2.42 to 6.30 t ha^{-1} in 2023, from 2.76 to 7.50 t ha^{-1} in 2024, from 2.39 to 5.34 t ha^{-1} in 2025, and from 1.97 to 7.10 t ha^{-1} in 2026 as fertilization increased from N0P0 to N120P80. The increase from N0P0 to N60P0 exceeded the 0.1 % LSD for factor A in every year, and the addition of phosphorus to the N60 regime also resulted in highly significant yield increases. These results confirm that the baseline fertilization level largely

determined yield potential and that K effects should be interpreted within each N-P regime rather than as the effect of an isolated factor (Duncan et al. 2018; Lollato et al. 2019).

The main effect of K, averaged across N-P fertilization regimes, was positive in every year. Compared with K0, K120 increased the factor B mean by 0.53 t ha^{-1} in 2022, 0.99 t ha^{-1} in 2023, 0.80 t ha^{-1} in 2024, 0.59 t ha^{-1} in 2025, and 0.46 t ha^{-1} in 2026; all differences exceeded the 5 % LSD for factor B. However, the response was not linear at the higher K rates. In 2026, for example, factor B means were 5.25 t ha^{-1} at K80 and 5.23 t ha^{-1} at K120, indicating that a plateau had been reached. Declining marginal yield gains with increasing K rates have also been reported when crop K requirements are nearly satisfied or when soil K availability becomes less limiting (Zhan et al. 2016; Fontana et al. 2022).

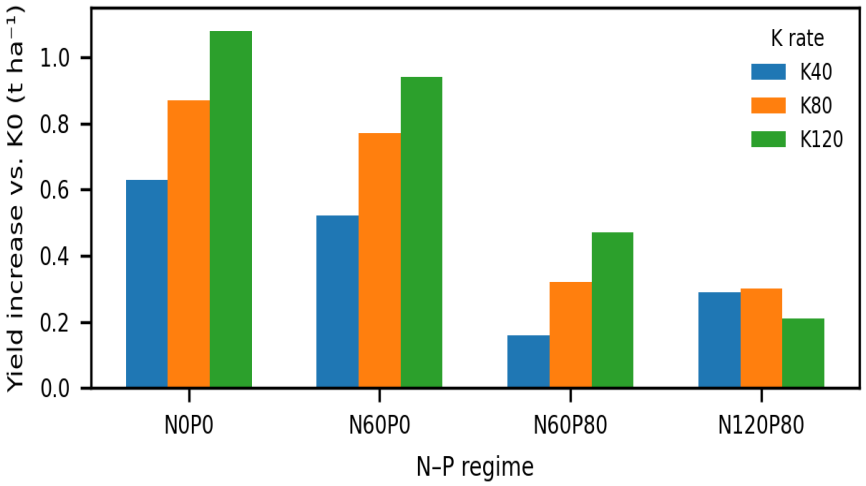


Figure 2. Five-year mean wheat grain yield increase relative to K0 under different N-P fertilization regimes, calculated from the mean yields obtained during 2022-2026.

The magnitude of the response to K decreased as the N-P fertilization regime became more favorable. Under N0P0, the five-year mean increased from 1.80 t ha^{-1} at K0 to 2.88 t ha^{-1} at K120 (+1.08 t ha^{-1}). Under N60P0, the corresponding increase was 0.94 t ha^{-1}, while under N60P80 it declined to 0.47 t ha^{-1}. Under N120P80, the five-year means were 6.56, 6.85, 6.86, and 6.77 t ha^{-1} for K0, K40, K80, and K120, respectively. Thus, the multi-year response reached a plateau in the K40-K80 range, and K120 provided no additional yield advantage. Under this high N-P regime, the K120-K0 differences remained below the 5 % LSD for BxA in all five years. Therefore, the central finding is not the identification of a single optimal K rate, but the progressive decline in the marginal response to K as N and P nutrition improved.

Interannual variability was also important. The overall mean across the 16 treatments was approximately 5.47 t ha^{-1} in 2022, 4.79 t ha^{-1} in 2023, 5.42 t ha^{-1} in 2024, 4.04 t ha^{-1} in 2025, and 5.09 t ha^{-1} in 2026. The lowest mean occurred in 2025, following the 2024-2025 agricultural year, when precipitation totaled only 438.0 mm (-223.8 mm relative to the reference mean). The 2021-2022 agricultural year was

also dry (508.3 mm; -155.4 mm), whereas 2022-2023 had above-average precipitation. For the 2026 harvest, the 2025-2026 agricultural year received 781.0 mm precipitation, 141.3 mm above the multi-year mean, with a mean temperature of 12.7 °C, equal to the reference value. Differences in yield levels among years should be interpreted in the context of precipitation distribution during the growing season, temperature, soil-water reserves, and nutrient supply, which act concurrently. The physiological roles of K in osmotic regulation and stomatal function provide a mechanistic basis for interpreting K responses under water deficit (Zörb et al. 2014), and research has shown improved wheat performance under drought following K application (Liu et al. 2026). For the Dropia cultivar, Babeanu et al. (2019) also reported changes in chlorophyll and osmolyte contents under water-deficit conditions. Related research in maize has examined antioxidant enzyme activities and proline content under PEG-induced water stress (Paunescu et al. 2016a), extending the biochemical context of water-stress responses beyond wheat.

Overall, the results support the principle of balanced mineral nutrition: the yield response to one nutrient depends on the availability of the other nutrients and on the soil's capacity to supply them. In this experiment, K fertilization was more effective in increasing yield under the lower N-P regimes, whereas the marginal benefit of K diminished at higher N-P levels. This trend is consistent with the literature on nutrient interactions in wheat (Lollato et al. 2019; Fontana et al. 2022; Zhang et al. 2026).

CONCLUSIONS

The N-P fertilization regime had a major influence on wheat grain yield, with differences among the four regimes being statistically significant in each experimental year.

Potassium fertilization increased grain yield as a main factor in all years; however, the response was not proportional to successive increases in K rate.

The response to K was greater under N0P0 and N60P0 and diminished under N60P80 and N120P80. Under N120P80, the five-year mean yields at K40 and K80 were nearly identical, and K120 produced no additional yield increase.

The highest five-year mean grain yield, 6.86 t ha^{-1}, was obtained with N120P80K80. Based on mean yields during 2022-2026, this treatment achieved the highest yield among the fertilization combinations evaluated.

The results support the need for balanced N-P-K fertilization adapted to soil fertility status and annual environmental conditions.

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