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Impact of phosphorus levels on barley (*Hordeum vulgare* L.) crop productivity and nutrition under Satna conditions

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Abstract
The field experiment was conducted at A.K.S. University, Satna, during the winter season of 2022-23. The soil was silty clay-loam with a pH of 7.35, electrical conductivity of 0.22 dS/m, and organic carbon of 0.48%. 12 organic treatments were applied to the JB-1 variety of barley, with a uniform dose of 60 kg N and 30 kg K_2O/ha. The crop was grown according to the recommended practices. The results showed that applying phosphorus up to 60 kg/ha was beneficial for maximum yield, seed quality, and NPK uptake from the soil. The seed yield of barley was up to 35.38 q/ha, and the total N, P, and K uptake was 103.4 kg N, 17.09 kg P, and 137.0 kg K/ha, respectively. The addition of phosphorus up to 60 kg/ha improved residual soil properties like E.C., O.C., and available NPK/ha after barley harvest.

Keywords: Barley, NPK, organic, phosphorus

Introduction

Barley, the fourth largest grain crop globally, is used in various products and is primarily grown as animal fodder and malt for alcoholic beverages (Sharma *et al*. 2012) [8]. In 2017-18, barley was cultivated in 106 lakh hectares in India, with a record production of 1.67 million tons. However, 80% of Indian soils are low or medium in available Potassium (P), which varies with soil, fertilizers, and reaction products (Singh *et al*. 2017, Singh *et al*. 2014) [14, 10]. The solubility of P depends on the ionic form of P in the fertilizer. P is the second most widely occurring nutrient deficiency in cereal systems worldwide after nitrogen stress. It is also a structural component of metabolically active compounds in plants. Due to its interacting nature, P concentration and solubility in soils are low (Sushanta *et al*. 2014, Tripathi *et al*. 2013) [11, 12], making it a critical nutrient limiting plant growth. Phosphorus is the second most limiting nutrient in soils for crop production, with nearly 80% of Indian soils low to medium in available P. Despite the recommended fertilizer use, P balance is often negative. P is essential for plant growth and metabolism (Yaduvanshi *et al*. 2013) [13], and is the second most widespread nutrient deficiency in cereal systems worldwide after nitrogen stress. It is also a structural component of metabolically active compounds in plants (Shafi *et al*. 2020, Saket *et al*. 2017, Rasul *et al*. 2016) [6, 5, 4]. However, its concentration and solubility in soils are low due to its interacting nature, making P a critical nutrient limiting plant growth. Phosphorus reactions in soil impact crop growth and fertilizer efficiency. P fertilizers' efficiency is low due to their low solubility and interaction. Plant roots absorb phosphorus from the soil solution, with concentrations ranging from mg/L to 1 mg/L (Mishra *et al*. 2017) [3]. Roots absorb orthophosphate H_2PO_4 and HPO_4, but can also absorb organic phosphorus. Phosphorus moves to the root surface through diffusion.

Material and Methods

During the rabi season of 2022-2023 at AKS University experimental farm in Sherganj, Satna, the experiment was carried out using materials, methodology, and field and laboratory observations, including chemical analysis. The field soil was classified as silty clay-loam and samples were collected randomly from various locations to determine its physico-chemical properties before and after barley crop harvesting. The soil was neutral in reaction, low in nitrogen and sulphur, medium in E.C., organic matter, available phosphorus and potassium, and had a uniform topography with a mild slope for efficient drainage. Barley var. JB-58 was sown in rows 20 cm apart, with a seed rate of 120 kg/ha to maintain the optimum plant population. The seeds were sown manually, 2 cm deep in furrows, covered by a thin layer of soil.

Result and Discussion

The study found that increased phosphorus supply leads to higher yield attributes in plants due to root proliferation, increased nutrient concentration, and faster cell division and elongation. This promotes root branching, tiller development, plant height, and dry matter production, which in turn enhances photosynthetic activity of leaves. Additionally, increased phosphorus supply also increases assimilate translocation, resulting in improved yield attributes. Phosphorus application at 60 kg/ha significantly increased plant growth, spike length, and grain content compared to previous levels (4.96 spikes/plant, 9.92 cm spike length, 64.48 grains/spike).

The application of phosphorus up to 60 kg/ha significantly improved grain and straw yields compared to lower doses. The maximum yield was achieved with 60 kg P_2O_5/ha, followed by 55, 50, and 45 kg P_2O_5/ha. The higher yields were attributed to adequate phosphorus supply to plants, leading to better growth and yield attributes. The lowest yield was observed with 20 kg P_2O_5/ha due to poor growth, metabolic processes, and yield attributes.

The study found that the N, P, and K contents in barley grain and straw were significantly influenced by the supply of different levels of phosphorus. The application of phosphorus up to 60 kg/ha increased the concentrations of these nutrients, with the N content being 1.94 and 0.56%, P content being 0.237 and 0.14%, and K content being 0.50 and 1.92%. This could be due to better root-growth, increased available P in soil, and the JB-58 genotype's genetically built-up character, which maintained better harmony between photosynthesis and P-nutrient translocation towards the grain. The percentage of N and P contents was higher in barley grain than in its straw, while the reverse was true for K content.

Total phosphorus uptake by barley plants, which includes nitrogen, phosphorus, and potassium, is influenced by production levels, applied phosphorus, and soil type. The uptake of these nutrients by grain and straw significantly increases with phosphorus levels up to 60 kg/ha. The maximum uptake of nitrogen was recorded at 60 kg P_2O_5/ha, followed by potassium at 55, 50, and 45 kg P_2O_5/ha. The increase in phosphorus uptake is attributed to the balanced nutritional environment provided by added phosphorus and higher photosynthesis efficiency, which promotes growth and crop yield. The higher nutrient uptake with increasing P levels is mainly due to improved nitrogen, phosphorus, and potassium content, coupled with higher grain and straw yield, resulting in higher nutrient uptake.

The application of increasing doses of phosphorus from 20 to 40 kg P_2O_5/ha increased soil pH and organic carbon levels, compared to the control. This increase was attributed to decreased CO_2 production and organic acids. The EC was slightly enhanced due to increased P-levels. The organic carbon reduced from 0.48% in the control and lowest dose of applied P, but increased with increasing levels of phosphorus. The application of phosphorus also increased available nitrogen in post-harvest soil, attributed to enhanced root-growth and mineralization of organic portions in the soil rhizosphere. The available-phosphorus content increased with the application of phosphorus up to 60 kg P_2O_5/ha, indicating that the higher doses of applied phosphorus levels are beneficial for plant growth and development. This increase in P status may be attributed to increased concentration of P in soil solution due to its addition at different levels.

The study investigates the protein content in barley grain and finds that it increases significantly with phosphorus levels up to 60 kg/ha. The highest protein content (12.13%) was obtained from P60, which has the highest N-content (1.94%) under P60 level. Phosphorus improves seed quality by regulating photosynthesis, root enlargement, and better microbial activities. The variation in protein content under P-levels may be due to varied N-concentration in the grain, resulting in differences in protein synthesis through amino acids due to N-metabolism.

Table 1: Yield-attributes and yield of barley as influenced by phosphorus levels.

S. No.	Treatments	Spikes per plant	Length of spike (cm)	Grains per spike	Grain yield (q/ha)	Straw yield (q/ha)	Seed protein (%)
T_1	Control	3.27	6.65	51.73	22.65	48.86	11.25
T_2	20 kg P_2O_5/ha	3.70	6.96	53.50	25.16	52.00	11.50
T_3	25 kg P_2O_5/ha	3.89	7.18	55.92	27.92	53.86	11.63
T_4	30 kg P_2O_5/ha	3.93	7.75	58.54	28.56	54.65	11.69
T_5	35 kg P_2O_5/ha	4.10	8.32	60.18	30.15	56.90	11.75
T_6	40 kg P_2O_5/ha	4.26	8.80	61.44	30.88	57.45	11.88
T_7	45 kg P_2O_5/ha	4.37	9.05	62.72	31.78	58.96	11.94
T_8	50 kg P_2O_5/ha	4.55	9.36	63.84	32.12	60.55	12.00
T_9	55 kg P_2O_5/ha	4.74	9.60	64.05	33.70	61.40	12.06
T_{10}	60 kg P_2O_5/ha	4.96	9.92	64.48	35.38	62.12	12.13
	S.Em$\pm$	0.019	0.19	0.36	0.46	0.37	0.03
	C.D. (P=0.05)	0.055	0.55	1.06	1.32	1.08	0.08

Table 2: Nutrient content (%) and uptake by grain and straw of barley as influenced by phosphorus levels

S. No.	Treatments	N-content (%)		P-content (%)		K-content (%)		N-uptake (kg/ha)			P-uptake (kg/ha)			K-uptake (kg/ha)		
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	Control	1.80	0.46	0.182	0.094	0.44	1.80	40.77	22.48	63.25	4.12	4.59	8.71	9.97	87.95	97.92
T_2	20 kg P_2O_5/ha	1.84	0.48	0.206	0.103	0.45	1.83	46.29	24.96	71.25	5.18	5.36	10.54	11.32	98.28	109.60
T_3	25 kg P_2O_5/ha	1.86	0.50	0.218	0.112	0.46	1.85	51.93	26.93	78.86	6.09	6.03	12.12	12.84	99.64	112.48
T_4	30 kg P_2O_5/ha	1.87	0.52	0.219	0.121	0.47	1.86	53.41	28.42	81.83	6.25	6.61	12.86	13.42	101.65	115.07
T_5	35 kg P_2O_5/ha	1.88	0.52	0.220	0.126	0.47	1.88	56.68	29.59	86.27	6.63	7.17	13.80	14.17	106.97	121.14
T_6	40 kg P_2O_5/ha	1.90	0.53	0.225	0.127	0.48	1.89	58.67	30.45	89.12	6.95	7.30	14.25	14.82	108.58	123.40
T_7	45 kg P_2O_5/ha	1.91	0.54	0.229	0.132	0.49	1.90	60.70	31.84	92.54	7.28	7.78	15.06	15.57	112.02	127.59
T_8	50 kg P_2O_5/ha	1.92	0.55	0.228	0.137	0.49	1.88	61.67	33.30	94.97	7.32	8.30	15.62	15.74	113.83	129.57
T_9	55 kg P_2O_5/ha	1.93	0.55	0.232	0.138	0.49	1.90	65.04	33.77	98.81	7.82	8.47	16.29	16.51	116.66	133.17
T_{10}	60 kg P_2O_5/ha	1.94	0.56	0.237	0.140	0.50	1.92	68.64	34.79	103.3	8.39	8.70	17.09	17.69	119.27	136.96
	S.Em$\pm$	0.014	0.01	0.005	0.003	0.02	0.26	0.38	0.47	0.85	0.10	0.10	0.20	0.19	0.56	0.75
	C.D. (P=0.05)	0.04	0.03	0.013	0.008	0.05	0.075	1.09	1.35	0.44	0.29	0.29	0.58	0.55	1.61	2.16

Conclusion
The study found that applying phosphorus up to 60 kg/ha to barley yielded maximum yield, seed quality, and maximum NPK uptake from the soil. The seed yield reached 35.38 q/ha and the total N, P, and K uptake was 103.4 kg N, 17.09 kg P, and 137.0 kg K/ha, respectively. The addition of phosphorus improved residual soil properties like E.C., O.C., and available NPK/ha post-harvest.

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