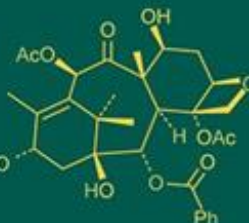
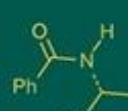
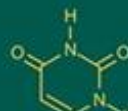
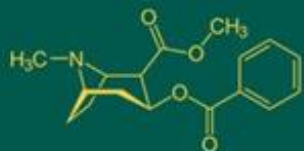


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Effect of different sources of nutrient management practices on grain quality, nutrient uptake and soil fertility in wheat (*Triticum aestivum* L.)

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Abstract

A field experiment was conducted at Raja Balwant Singh College Research Farm, Bichpuri (Agra) during 2018 -19 to assess the “Effect of nutrient management practices on protein content, nutrient uptake and nutrient availability in wheat (*Triticum aestivum* L.)”. The experiment was laid out in a Randomized Block Design with eight treatments involving different combinations of recommended NPK, farmyard manure (FYM), sulphur, zinc and higher fertilizer dose. Results revealed that protein content in grain and straw and protein yield were significantly improved under all nutrient treatments over control. The highest grain protein content (13.37%) was recorded under T₈ while protein yield was marginally higher under T₇, indicating comparable effectiveness of both treatments. Nutrient uptake of nitrogen, phosphorus, potassium, sulphur and zinc was also significantly enhanced, with maximum values observed under T₇ followed closely by T₈. Post-harvest soil nutrient availability (N, P, K, S and Zn) was also improved under integrated nutrient management treatments compared to control. The improvement in protein content, nutrient uptake and soil nutrient status was attributed to balanced nutrient supply, improved root activity and enhanced nutrient use efficiency under integrated nutrient management and higher fertilizer dose.

Keywords: Wheat, protein content, nutrient uptake, nutrient availability, integrated nutrient management, fym, zinc, sulphur

Introduction

Wheat (*Triticum aestivum* L.) is one of the world's principal cereal crops and its productivity as well as grain quality are strongly influenced by nutrient availability and balanced fertilization strategies (Yu, 2025)^[1]. Nutrient management is a key agronomic factor that affects not only crop yield and quality but also nutrient uptake efficiency and soil fertility status (Yu, 2025; Gund et al., 2022)^[1,2]. Conventional reliance on sole inorganic fertilizers often results in nutrient imbalances, reduced nutrient use efficiency and progressive declines in soil fertility (Yu, 2025)^[1]. Integrated Nutrient Management (INM), involving combined application of inorganic fertilizers with organic amendments and micronutrients, has been proposed as an effective approach to enhance nutrient availability, crop performance and soil health (Sharma & Tomar, 2025)^[3].

Several field studies have demonstrated that INM significantly improves wheat growth, grain protein content, nutrient uptake and soil fertility relative to control or sole fertilizer treatments. For example, combined application of chemical fertilizers with organic amendments and micronutrients increased protein concentration and grain yield while improving soil nutrient pools (Sharma & Tomar, 2025)^[3]. Field experiments have also reported substantial increases in uptake of nitrogen, phosphorus and potassium in wheat under integrated nutrient regimes relative to unfertilized controls (Chesti, Kohli & Sharma, 2013)^[4]. Additionally, the inclusion of organic sources such as farmyard manure or vermicompost alongside inorganic fertilizers has been shown to enhance nutrient use efficiency and post-harvest soil fertility (Gund et al., 2022)^[2]. Field experiments conducted under alluvial soil conditions demonstrated that the combined use of organic manures such as farmyard manure and vermicompost with chemical fertilizers significantly increased the uptake of nitrogen, phosphorus, potassium, sulphur and zinc by wheat, while also improving post-harvest soil nutrient pools compared with control treatments (Singh, 2019)^[5]. Despite these findings, the effects of high levels of combined macro-, secondary and micronutrients with organic manure on wheat grain quality, multi-nutrient uptake and soil fertility under specific field conditions remain inadequately quantified. Therefore, systematic evaluation

of integrated nutrient management practices is necessary to optimize nutrient strategies for improving wheat grain quality, nutrient uptake and sustaining soil fertility.

Materials and Methods

The experimental field was laid out in a Randomized Block Design with eight treatments and three replications. Treatments were applied as follows: T₁ (Control), T₂ (10 t FYM ha⁻¹), T₃ (120 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹), T₄ (120 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹ + 10 t FYM ha⁻¹), T₅ (120 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹ + 20 kg S ha⁻¹), T₆ (120 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹ + 5 kg Zn ha⁻¹), T₇ (120 kg N + 60 kg P₂O₅ + 40 kg K₂O ha⁻¹ + 20 kg S + 5 kg Zn + 10 t FYM ha⁻¹), and T₈ (150 kg N + 90 kg P₂O₅ + 60 kg K₂O ha⁻¹).

Wheat (*Triticum aestivum* L.) was sown at recommended seed rate and basal nutrients were applied according to treatment specifications. At harvest, grain and straw samples were oven-dried at 65±2 °C to constant weight and ground for analysis. Grain protein content (%) was calculated as % N×6.25 (Jones *et al.*, 1991) [6] and protein yield (qha⁻¹) was computed as [protein content (%)× grain yield (qha⁻¹)] / 100. Nitrogen content was determined by Kjeldahl method (Bremner, 1965) [7], phosphorus by vanado-molybdate yellow colour method (Jackson, 1973) [8], potassium by flame photometry, sulphur turbidimetrically, and zinc concentration using atomic absorption spectrophotometry after wet digestion (Wolf, 1971) [9]. Nutrient uptake (kg ha⁻¹ for N, P, K, S; g ha⁻¹ for Zn) was calculated as nutrient concentration (%) × corresponding dry matter yield (kg ha⁻¹) (Giller 2001) [10]. Post-harvest soil samples were air-dried, sieved (2 mm) and analyzed for available N by alkaline permanganate

(Subbiah & Asija, 1956), available P by Olsen's method (Olsen *et al.*, 1954) [11], available K by neutral ammonium acetate extraction (Jackson, 1973) [8], available S turbidimetrically, and available Zn by DTPA extraction followed by atomic absorption spectrophotometry (Lindsay & Norvell, 1978) [12]. Data were subjected to analysis of variance (ANOVA) for randomized block design and treatment differences were tested at P≤0.05 using critical difference (CD) values (Gomez & Gomez, 1984) [13].

Result and Discussion

Protein content and yield

Protein content in grain and straw, as well as protein yield, increased significantly with nutrient management practices compared to control (Table 1). The lowest grain protein content (11.87%) and protein yield (370.0qha⁻¹) were recorded under control, while all fertilized treatments showed improvement. The highest grain protein content was recorded under T₈ (13.37%), closely followed by T₇ (13.25%). However, protein yield was marginally higher under T₇ (736.3 q ha⁻¹) compared to T₈ (723.1 q ha⁻¹), indicating the advantage of integrated nutrient management in enhancing total protein production. The improvement in protein content and yield under integrated and higher fertilizer treatments may be attributed to enhanced nitrogen availability and its efficient assimilation into amino acids and proteins. The presence of sulphur further supports protein synthesis, while zinc plays a key role in enzyme activation and nitrogen metabolism, ultimately improving grain quality and protein accumulation. Similar findings in wheat have been reported by Paramesh *et al.* (2020) [14] and Singh (2019) [5].

Table 1: Effect of different nutrient management practices on quality of wheat.

S.No.	Treatment	Protein content (%)		Protein yield (q ha ⁻¹)
		Grain	Straw	
T1	Control	11.87	3.6	370.0
T2	10 t FYM ha ⁻¹	12.50	3.8	449.3
T3	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹	12.81	4.3	570.6
T4	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 10 t FYM ha ⁻¹	13.12	4.4	667.1
T5	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S ha ⁻¹	13.00	4.3	625.0
T6	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 5 kg Zn ha ⁻¹	13.06	4.1	615.2
T7	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S + 5 kg Zn + 10 t FYM ha ⁻¹	13.25	4.5	736.3
T8	150 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O ha ⁻¹	13.37	4.6	723.1
	SEm	0.35	0.13	11.51
	CD (P=0.05)	1.02	0.38	33.49

Nitrogen content and uptake

Nitrogen content in grain and straw, as well as nitrogen uptake, was significantly influenced by nutrient management practices (Table 2). The lowest nitrogen content in grain (1.90%) and straw (0.57%) along with minimum nitrogen uptake was recorded under control. Application of recommended NPK and integrated nutrient treatments improved nitrogen concentration and uptake in both grain and straw over control. The highest nitrogen content in grain (2.14%) and straw (0.73%) was recorded under T₈, closely followed by T₇. However, nitrogen uptake in grain (117.8 kg ha⁻¹) and straw (49.0kgha⁻¹) was

slightly higher under T₇ compared to T₈, indicating better nutrient use efficiency under integrated nutrient management. The increase in nitrogen content and uptake may be attributed to increased nitrogen availability in soil, improved root activity and better assimilation of nitrogen into plant tissues. The presence of FYM enhances nutrient retention and mineralization, while sulphur and zinc play a key role in nitrogen metabolism and enzyme activation, thereby improving uptake efficiency. Similar results in wheat have been reported by Singh *et al.* (2019) [5] and Kumar *et al.* (2023a) [15].

Table 2: Effect of different nutrient management practices on nitrogen content and uptake by wheat.

S.No.	Treatment	Nitrogen content (%)		Nitrogen uptake (kg ha ⁻¹)	
		Grain	Straw	Grain	Straw
T1	Control	1.90	0.57	59.2	23.1
T2	10 t FYM ha ⁻¹	2.00	0.60	71.9	28.2
T3	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹	2.05	0.64	41.3	37.3

T4	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 10 t FYM ha ⁻¹	2.10	0.70	106.8	42.7
T5	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S ha ⁻¹	2.08	0.68	99.9	40.7
T6	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 5 kg Zn ha ⁻¹	2.09	0.66	98.5	38.1
T7	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S + 5 kg Zn + 10 t FYM ha ⁻¹	2.12	0.72	117.8	49.0
T8	150 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O ha ⁻¹	2.14	0.73	115.8	48.3
	SEm	0.010	0.004	3.10	1.10
	CD (P=0.05)	0.029	0.011	9.08	3.32

Phosphorus content and uptake

Phosphorus content in grain and straw, along with phosphorus uptake, was significantly influenced by nutrient management practices (Table 3). The lowest phosphorus content in grain (0.21%) and straw (0.10%) and minimum uptake was recorded under control. All fertilized treatments improved phosphorus concentration and uptake over control, indicating better nutrient availability and assimilation. The highest phosphorus content in grain (0.28%) and straw (0.18%) was recorded under T₇, whereas T₈ remained statistically comparable. Similarly, maximum phosphorus uptake in grain (15.5 kg ha⁻¹) and straw (12.2 kg ha⁻¹) was observed under T₇, followed by T₈ (14.6 and

11.2 kg ha⁻¹, respectively). This indicates that integrated nutrient management slightly improved phosphorus uptake efficiency compared to higher fertilizer dose alone. The improvement in phosphorus status may be attributed to enhanced root proliferation, better soil microbial activity and improved phosphorus solubilization in the presence of FYM. Organic acids released during decomposition of FYM help in reducing phosphorus fixation, thereby increasing its availability to plants. Sulphur and zinc also contribute indirectly by improving root growth and metabolic activity, leading to higher nutrient uptake. Similar results in wheat have been reported by Singh *et al.* (2019) [5] and Paramesh *et al.* (2020) [14].

Table 3: Effect of different nutrient management practices on phosphorus content and uptake by wheat.

Treatment	Phosphorus content (%)		Phosphorus uptake (kg ha ⁻¹)	
	Grain	Straw	Grain	Straw
T1 Control	0.21	0.10	6.5	4.1
T2 10 t FYM ha ⁻¹	0.23	0.12	8.3	5.6
T3 120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹	0.26	0.15	11.6	8.6
T4 120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 10 t FYM ha ⁻¹	0.27	0.17	13.7	10.4
T5 120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S ha ⁻¹	0.26	0.15	12.5	8.9
T6 120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 5 kg Zn ha ⁻¹	0.24	0.14	11.3	8.1
T7 120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S + 5 kg Zn + 10 t FYM ha ⁻¹	0.28	0.18	15.5	12.2
T8 150 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O ha ⁻¹	0.27	0.17	14.6	11.2
SEm	0.004	0.003	0.46	0.27
CD (P=0.05)	0.011	0.008	1.35	0.79

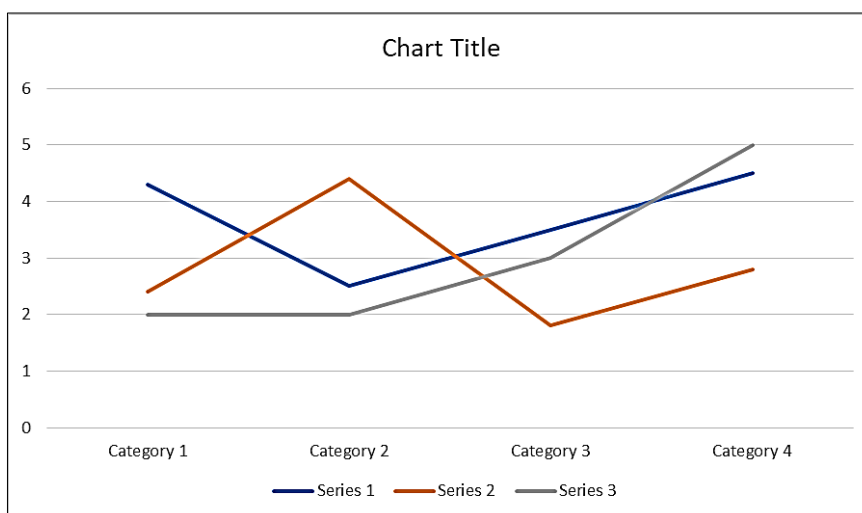


Fig 3: Effect of different nutrient management practices on phosphorus content and uptake by wheat

Potassium content and uptake

Potassium content in grain and straw, along with potassium uptake, was significantly influenced by nutrient management practices (Table 4). The lowest values were recorded under

control, indicating poor nutrient supply and uptake under unfertilized conditions. All fertilized treatments improved potassium concentration and uptake in both grain and straw. The highest potassium content in grain (0.70%) and straw

(2.16%) was recorded under T₇, which was statistically at par with T₈. Similarly, maximum potassium uptake in grain (38.9 kg ha⁻¹) and straw (147.1 kg ha⁻¹) was observed under T₇, followed closely by T₈. This indicates slightly better nutrient use efficiency under integrated nutrient management compared to higher RDF alone. The improvement in potassium status may

be attributed to enhanced root growth, improved soil biological activity and better nutrient availability under FYM application. Organic manure improves soil cation exchange capacity, thereby enhancing potassium retention and uptake. Similar findings in wheat have been reported by Singh *et al.* (2019)^[5] and Kumar *et al.* (2023a)^[15].

Table 4: Effect of different nutrient management practices on potassium content and uptake by wheat.

S.No.	Treatment	Potassium content (%)		Potassium uptake (kg ha ⁻¹)	
		Grain	Straw	Grain	Straw
T ₁	Control	0.60	1.95	18.7	79.0
T ₂	10 t FYM ha ⁻¹	0.63	2.00	22.6	94.1
T ₃	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹	0.66	2.10	29.4	115.2
T ₄	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 10 t FYM ha ⁻¹	0.69	2.15	35.1	131.2
T ₅	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S ha ⁻¹	0.67	2.12	32.2	126.1
T ₆	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 5 kg Zn ha ⁻¹	0.65	2.10	30.6	121.4
T ₇	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S + 5 kg Zn + 10 t FYM ha ⁻¹	0.70	2.16	38.9	147.1
T ₈	150 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O ha ⁻¹	0.70	2.15	37.9	142.1
	SEm	0.007	0.011	1.17	1.95
	CD (P=0.05)	0.020	0.032	3.44	5.73

Sulphur content and uptake

Sulphur content in grain and straw, along with sulphur uptake, was significantly affected by nutrient management practices (Table 5). The lowest values were recorded under control, while all fertilized treatments showed improvement. The highest sulphur content in grain (0.31%) and straw (0.17%) was recorded under T₇, which was comparable with T₈. Similarly,

maximum sulphur uptake in grain (17.2 kg ha⁻¹) and straw (11.5 kg ha⁻¹) was also observed under T₇, followed closely by T₈. Highest sulphur content and uptake may be attributed to direct sulphur application along with FYM-induced enhancement of nutrient availability and microbial activity. Similar results in wheat have been reported by Singh *et al.* (2019)^[5].

Table 5: Effect of different nutrient management practices on sulphur content and uptake by wheat.

S.No.	Treatment	Sulphur content (%)		Sulphur uptake (kg ha ⁻¹)	
		Grain	Straw	Grain	Straw
T ₁	Control	0.24	0.11	7.5	4.5
T ₂	10 t FYM ha ⁻¹	0.25	0.12	9.0	5.6
T ₃	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹	0.28	0.14	12.5	7.7
T ₄	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 10 t FYM ha ⁻¹	0.30	0.16	15.2	9.8
T ₅	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S ha ⁻¹	0.30	0.17	15.4	9.9
T ₆	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 5 kg Zn ha ⁻¹	0.27	0.14	12.7	8.1
T ₇	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S + 5 kg Zn + 10 t FYM ha ⁻¹	0.31	0.17	17.2	11.5
T ₈	150 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O ha ⁻¹	0.29	0.15	15.7	9.9
	SEm	0.004	0.003	0.49	0.21
	CD (P=0.05)	0.011	0.008	1.44	0.62

Zinc content and uptake

Zinc content in grain and straw, along with zinc uptake, was significantly influenced by nutrient management practices (Table 6). The lowest values were recorded under control, while all fertilized treatments showed improvement. The highest zinc content in grain (36.5 mg kg⁻¹) and straw (25.0 mg kg⁻¹) was observed under T₇, whereas T₇ also recorded maximum zinc

uptake in grain (202.8 g ha⁻¹) and straw (170.2 g ha⁻¹), followed closely by T₈. The improvement in zinc status may be attributed to direct zinc application along with FYM-mediated enhancement of micronutrient availability and reduced soil fixation. Similar findings in wheat have been reported by Kumar *et al.* (2023b)^[16] and Singh *et al.* (2019)^[5].

Table 6: Effect of different nutrient management practices on zinc content and uptake by wheat.

S.No.	Treatment	Zinc content (mg kg ⁻¹)		Zinc uptake (g ha ⁻¹)	
		Grain	Straw	Grain	Straw
T ₁	Control	29.0	20.0	90.3	81.0
T ₂	10 t FYM ha ⁻¹	30.0	21.0	107.8	98.7
T ₃	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹	31.6	23.0	140.7	126.2
T ₄	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 10 t FYM ha ⁻¹	35.0	24.5	178.0	149.5
T ₅	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S ha ⁻¹	33.5	24.0	161.0	142.8
T ₆	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 5 kg Zn ha ⁻¹	34.5	24.6	173.5	138.7
T ₇	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S + 5 kg Zn + 10 t FYM ha ⁻¹	36.5	25.0	202.8	170.2
T ₈	150 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O ha ⁻¹	32.6	23.5	176.4	155.4
	SEm	0.81	0.41	3.10	1.78
	CD (P=0.05)	2.38	1.20	9.11	5.23

Available N, P, K, S and Zn

Nutrient management practices significantly influenced the nutrient content of wheat (Table 7). The lowest N, P, K, S and Zn contents were recorded under control, indicating poor nutrient availability under unfertilized conditions. All fertilized treatments improved nutrient concentration in plant parts over control. The highest nutrient contents were recorded either under T₇ or T₈, with both treatments showing very close and statistically comparable values. Nitrogen (168.0–170.1 kg ha⁻¹), phosphorus (14.5–15.0 kg ha⁻¹) and potassium (142.0–145.0 kg

ha⁻¹) were highest under T₇ and T₈, while sulphur (13.5 mg kg⁻¹) and zinc (0.72–0.70 mg kg⁻¹) were also maximum under these treatments. Availability of nutrients improvement may be attributed to balanced nutrient supply, enhanced root growth and improved nutrient uptake efficiency. FYM improved soil biological activity and nutrient mineralization, while sulphur and zinc enhanced metabolic processes and nutrient assimilation. Similar findings in wheat have been reported by Singh *et al.* (2019)^[5] and Kumar *et al.* (2023a)^[15].

Table 7: Effect of different nutrient management practices on nutrient availability of soil after harvest of wheat.

S.No.	Treatment	N (kg ha ⁻¹)	P (kg ha ⁻¹)	K (kg ha ⁻¹)	S (mg kg ⁻¹)	Zn (mg kg ⁻¹)
T ₁	Control	125.0	8.5	96.0	8.0	0.50
T ₂	10 t FYM ha ⁻¹	136.5	10.0	118.5	8.6	0.55
T ₃	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹	144.2	10.5	128.0	9.0	0.52
T ₄	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 10 t FYM ha ⁻¹	160.0	13.6	135.0	11.0	0.62
T ₅	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S ha ⁻¹	154.0	12.1	130.0	13.4	0.60
T ₆	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 5 kg Zn ha ⁻¹	155.2	11.6	126.0	10.5	0.70
T ₇	120 kg N + 60 kg P ₂ O ₅ + 40 kg K ₂ O ha ⁻¹ + 20 kg S + 5 kg Zn + 10 t FYM ha ⁻¹	168.0	14.5	142.0	13.5	0.72
T ₈	150 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O ha ⁻¹	170.1	15.0	145.0	13.5	0.70
	SEm	1.29	0.17	1.32	0.82	0.005
	CD (P=0.05)	3.79	0.50	3.88	2.41	0.0114

Conclusion

The study demonstrates that nutrient management practices markedly influence protein status, nutrient uptake and post-harvest nutrient availability in wheat. Application of balanced fertilization along with FYM, sulphur and zinc significantly improved protein content in grain and straw, enhanced uptake of N, P, K, S and Zn, and improved soil nutrient availability compared to control. Although T₈ recorded the highest grain protein content, T₇ performed comparably and showed relatively higher nutrient uptake along with better nutrient availability in soil. This indicates that integrated nutrient management ensures efficient nutrient utilization while maintaining soil fertility, and can serve as a more sustainable option for improving nutritional quality and soil health in wheat-based cropping systems.

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