**Effect of different fertilizer recommendation approaches on yield, profitability and nutrient uptake by wheat (*Triticum aestivum*) in acid *Alfisols*of North Western Himalayas**


## Abstract

A field experiment was conducted on wheat crop during *rabi*, 2019-20 at the experimental farm of Soil Science, CSKHimachal Pradesh Krishi Vishvavidyalaya, Palampur. The studycomprised of nine treatments (control, farmers' practice, general recommended dose, soil test based fertilizer application, Soil Test Crop Response (STCR) based application of fertilizers for target yield of 25 q $ha^{-1}$ and target yield of 35 q $ha^{-1}$ without farmyard manure (FYM),Soil Test Crop Response based Integrated plant nutrition system (STCR-IPNS) application of fertilizers for target yield of 25 q $ha^{-1}$and target yield of 35 q $ha^{-1}$with FYM @ 5 t $ha^{-1}$and one Zero Budget Natural Farming (ZBNF) treatment).The experiment was laid out in randomized block design with nine treatments that were replicated thrice. The effects of different fertilizers recommendation approaches on yield, profitability and nutrient uptakein wheat were evaluated.Different treatments had a significant effect on the yield and nutrient uptake of wheat crop. STCR treatment for the target yield of 35 q $ha^{-1}$ with FYM resulted in the highest wheat grain yield (35.4 q $ha^{-1}$).However, the highest BC ratio was recorded in treatment for target yield 35 q $ha^{-1}$ without FYM followed by treatment 25 q $ha^{-1}$ without FYM. A significant increase in N, P, K and micronutrients (Fe, Mn, Zn and Cu) uptake by wheat grain and straw was observed in STCR based target yield plots as compared to general recommended dose, farmers' practice, and control. The STCR-based target yield approach maximizes economic yields by supplying nutrients precisely according to crop requirements, thereby enhancing fertilizer use efficiency and conserving expensive fertilizers.



**Keywords:** Wheat, Soil test crop response (STCR), Yield, Uptake, Profitability


## Introduction

Wheat (*Triticum aestivum*) is the primary staple food for around two billion people, accounting for 36 per cent of the world's population. It stands as a cornerstone crop in bolstering global food security, accounting for approximately 20 per cent of the world's dietary energy and protein intake (Gooding and Shewry, 2022). Beside food security it also plays a crucial role in economic stability and agricultural sustainability, making it an essential crop in both developed and developing countries. In India, it is the second most important cereal crop after rice and is a crucial component of the daily human diet.100 g of wheat grains contain 71.1 g of carbohydrates, 13.7 g of protein, 2.47 g oflipid (fat) and 339 k cal of energy (Anonymous, 2019).

In the current era, world faces the formidable challenge of producing sufficient food, fodder, fibre, and fuel to meet the diverse needs of its burgeoning human population. According to the United Nations, the global population is expected to reach 8.5 billion by 2030, 9.8 billion by 2050, and grow up to 11.2 billion by the end of the century(Anonymous, 2017).“It has been estimated thatthe world would need to produce 70 per cent more food in 2050 to fulfil the requirement of its exponentially growing population”(Tripathi *et al.*,2019).As population growth rapidly accelerates, the pressure on food production intensifies, posing a significant threat to global food security. “A growing human population demands increased food production. Farmers try to meet that demand by intensive farming, using fertilizers and pesticides. While intensive agriculture has been instrumental in feeding a growing global population and producing food more efficiently, it has also raised concerns regarding sustainability, environmental degradation, animal welfare, and the loss of biodiversity.Some intensive agricultural activities such as the cultivation of monocultures and imbalanced and inadequate use of fertilizers not only results in poor yields but also deteriorates soil fertility and increased multiple nutrient deficiencies” (Boldea*et al.*, 2015). Over the past three decades in India, the intensive cultivation of high-yielding wheat varieties has heavily depleted soil nutrients. This has led to increased reliance on chemical fertilizers to boost yields. Chemical fertilizers play a pivotal role in modern agricultureby providing essential nutrients that enhance crop yields. However, over-reliance on chemical fertilizers can have adverse effects on soil health and environment. Heavy use of fertilizers, can lead to soil degradation, water pollution, and biodiversity loss.

As we navigate the complexities of the 21$^{st}$ century, sustainable practices which prioritize soil health isa key to ensure that wheat remains a reliable source of nutrition and prosperity for future generations. Use of sustainable agricultural practice such as,precision farming, and integrated nutrient management practicesincluding the balanced use of organic and inorganic sources of fertilizerscan preserve soil health, enhance resilience to climate change, and ensure long-term productivity while minimizing environmental impacts.

The Soil Test Crop Response (STCR) approach for fertilizer application, first introduced by Trough (1960), is a scientific method for balanced fertilization, ensuring equilibrium between applied and soil-available nutrients. The method of fertilizer recommendations based on targeted yield of the crops also called “Prescription Based Fertilizer Recommendations”, avoid wide variations in soil rating limits, as it substitutes the exact values for soil available N, P and K. “The Soil Test Crop Response (STCR) approach ensures a balanced supply of necessary nutrients to crops, avoiding both overuse and underuse of fertilizers. This method not only prevents environmental hazards but also maximizes returns. By meeting crop requirements, STCR produces the economic yields, ensures quality produce, and avoids excessive nutrient levels”(Boldea*et al.*, 2015).“The Soil Test Crop Response (STCR) approach for fertilizer application, integrates soil and plant analyses scientifically.Under the target yield approach, fertilizer doses are precisely prescribed using adjustment equations. It has emerged as a refined method for optimizing nutrient use from fertilizers and soil resources. The STCR approach helps farmers by optimizing fertilizer use, enabling them to achieve desired yields while considering their economic conditions”(Bhatt *et al.*, 2021).

Combining targeted yield-based fertilizer application with organic sources like farmyard manure (IPNS-STCR) enhances soil biological activity, physical properties, and chemical properties of soil. This holistic approach promotes ecologically sound nutrient management which not only improves soil health but also increases crop yields synergistically.Therefore, this research work was undertaken to evaluate the effect of different fertilizer recommendation approaches on yield, profitability and nutrient uptake in wheat crop.

## Material and methods

### Experimental details

The field experiment was conducted on wheat during *rabi*, 2019-20 at the Experimental farmof Department of Soil Science, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental farm is located at 32° 06' N latitude and 76° 3' E longitude at an elevation of 1290 m above mean sea level in Kangra district of Himachal Pradesh.

### Climate and weather

The climate of the experimental site is characterized as wet-temperate. The region has mild summers from March to June and cool winters during December to February with high rainfall during monsoon months. The region receives an average annual rainfall of 2500 mm to 3000 mm per annum with 75% of the showers occurring mainly during monsoon months (June - September). During *rabi, 2019*-2020, the region received a total rainfall of 788 mm and the mean maximum and minimum temperatures were 19.6°C and 17.6°C, respectively.

### Soil characterstics

The soil of the experimental site belonged taxonomically to the order *Alfisol* under the sub-group *Typic Hapludalf*. The soils of the experimental site were silty clay loam in texture, acidic in reaction with pH 5.47, medium in organic carbon 7.80 g $kg^{-1}$, low in available nitrogen 217 kg $ha^{-1}$, high in available phosphorus 28 kg $ha^{-1}$ and medium in soil available potassium 234 kg $ha^{-1}$ status.

### Experimental details

The experiment was laid out in a randomized block design consisting of nine treatment combinations (Table 1). The treatments were replicated thrice with plot size of 15 $m^2$.The details of treatments used were as follows:

**Table 1. Treatment details of the experiment**

| Symbol | Description |
|---|---|
| $T_1$ | Control |
| $T_2$ | Farmers' practice |

| | |
|---|---|
| $T_3$ | General recommended dose |
| $T_4$ | Soil test based fertilizer application |
| $T_5$ | Fertilizer dose for target yield 25 q $ha^{-1}$ |
| $T_6$ | Fertilizer dose for target yield 25 q $ha^{-1}$ with FYM @ 5 t $ha^{-1}$ |
| $T_7$ | Fertilizer dose for target yield 35 q $ha^{-1}$ |
| $T_8$ | Fertilizer dose for target yield 35 q $ha^{-1}$ with FYM @ 5 t $ha^{-1}$ |
| $T_9$ | *Beejamrit* + *Jeevamrit* + *Ghanajeevamrit* |

Wheat (HPW-236) was taken as a test crop.The sowing of crop was done on 14$^{th}$ November, 2019 with a seed rate of 100 kg $ha^{-1}$.The row to row spacing was kept 22 cm. All the recommended cultural practices were followed during the entire crop growth. At the time of sowing, half dose of nitrogen and full doses of $P_2O_5$ and $K_2O$ were applied according to the treatments as a basal application. The remaining half dose of nitrogen was applied into two equal splits, one at the time of tillering and another during flowering stage. In $T_9$,*Ghanajeevamrit* @ 250 kg $ha^{-1}$ was incorporated in the soil before sowing of wheat. The wheat seeds were treated with *Beejamrit* @101 kg $ha^{-1}$ and then dried in shade before sowing. *Jeevamrit* @500 liters $ha^{-1}$ was also applied during sowing followed by its spray after 21 days interval with 1:10 dilution in water. Lantana was used for mulching. FYM was applied @5 t $ha^{-1}$ (dry wright basis) along with chemical fertilizers in all the Soil Test Crop Response based Integrated plant nutrition system(STCR-IPNS) treatments.

The following equations given by (Verma *et al.*, 2007) developed for computing the STCR-based fertilizers doses of N, $P_2O_5$ and $K_2O$ under wheatcropwere as follows:

$$FN = 5.27\ T - 0.25\ SN – 1.06\ ON$$

$$FP_2O_5 = 4.13\ T – 0.38\ SP – 0.98\ OP$$

$$FK_2O = 2.87\ T – 0.15\ SK – 0.55\ OK$$

In the above adjustment equations FN, $FP_2O_5$, $FK_2O$ are doses of N, $P_2O_5$ and $K_2O$, respectively in kg $ha^{-1}$. T is the yield target (q $ha^{-1}$), SN, SP and SK are soil available N, P and K contents before sowing of the crop, respectively in kg $ha^{-1}$. Whereas ON, OP and OK are N, P and K supplied by FYM, respectively in kg $ha^{-1}$.

**Laboratory studies**

For the chemical analysis of nutrient content in plant, representative grain and straw samples were collected after the harvest of wheat crop.The samples were then air dried and later kept in the hot air oven at 60-70°C for eight hours. The dried samples were then ground and stored in paper bags for subsequent analysis. The analytical methods employed for plant analysis are as follows:

**Table 2. Analytical methods used for FYM and plant analysis**

| Parameter | Method | References |
|---|---|---|
| Nitrogen | Micro-kjeldahl | Jackson (1973) |
| Phosphorus | Vanado-molybdo-phosphoric acid | Jackson (1973) |
| Potassium | Wet digestion | Black (1965) |
| Zn, Fe, Mn, Cu | Wet digestion | Jackson (1967) |

The nutrient uptake was calculated by multiplying (%) concentration of a nutrient with grain and straw yields (q $ha^{-1}$) on dry weight basis using the given formula:

$$Nutrient\ Uptake\ (kg\ ha^{-1}) = \frac{\%\ Concentration * yield\ (q\ ha^{-1})}{100}$$

Total uptake = uptake by grains + uptake by straw.

**Economic analysis**

The economics of the experiment was worked out in terms of net returns and BC ratio. Cost of cultivation (Rs $ha^{-1}$) was obtained by adding the costs of all the inputs and each operation involved during the experimental trial of wheat crop. Gross returns (Rs $ha^{-1}$) were calculated by multiplying yield of produce (q $ha^{-1}$) under different treatments with the price of the produce in the market. Net returns (Rs $ha^{-1}$) were computed by deducting the cost of inputs from gross returns and BC ratio was calculated by dividing gross returns with cost of cultivation.

**Results and Discussion**

**Effect of different fertilizers recommendation approaches on grain and straw yield of wheat**

**Grain and straw yield**

Application of fertilizers based on different approaches significantly influenced the grain and straw yield of wheat (Table 1). Wheat grain and straw yield varied from the lowest (14.4 q $ha^{-1}$)and (23.9q $ha^{-1}$) in $T_1$(control) to the highest (35.4 q $ha^{-1}$) and (53 q $ha^{-1}$) in $T_8$(target yield of 35 q $ha^{-1}$ with FYM), respectively.All the STCR based treatments were significantly superior with respect to the grain yield over the other treatments. Both the STCR based IPNS treatments were at par with their respective non-IPNS treatments with respect to thegrain yield and straw yield of wheat. Treatment $T_4$ (soil test based application of fertilizers) recorded significantly higher grain and straw yield compared to $T_2$ (farmers' practice), $T_9$ (treatment where*Beejamrit*, *Jeevamrit*, *Ghanajeevamrit*were applied along with mulch), and $T_1$ (control). However, it was at par with $T_3$ (where general recommended dose of fertilizers were appliedIncreased yield under STCR approach with and without FYM might be because of balanced use of fertilizers as per soil and crop demand for potential growth and development (Kumar *et al.,* 2023).(Singh *et al.*,2016) also revealed that the sole or combine application of fetilizerswith FYM based on target yield approach had a marked effect on grain and straw yields of wheat. Similar results were reported by (Sellamuthu *et al.*,2015).Yadahalli and Kammar (2017)also reported the highest yield under STCR approach in direct seeded rice.

**Effect of different fertilizers recommendation approaches on profitability of wheat**

The highest net returnsof Rs 77,695 ha$^{-1}$were manifested undertarget yield of 35 q ha$^{-1}$ without FYM ($T_7$) followed by the treatment with same yield target with FYM ($T_8$) Rs 69,649 ha$^{-1}$ (Table 1). Application of fertilizers based on soil test values ($T_4$) recorded net returns of Rs 49,374 ha$^{-1}$ which were Rs 6,170 ha$^{-1}$, Rs 26,846 ha$^{-1}$ and Rs 21,199 ha$^{-1}$ higher in comparison to general recommended dose ($T_3$), farmers' practice($T_2$) and *Beejamrit* + *Jeevamrit* + *Ghanajeevamrit*($T_9$).With respect to the benefit drawn per unit rupee invested on inputs, treatment target yield 35q ha$^{-1}$ without FYM ($T_7$) was the most remunerative followed by the treatment comprising of target yield 25 q ha$^{-1}$ without FYM ($T_5$) with the BC ratios of 3.58 and 3.08, respectively.Treatment farmers' practice ($T_2$) was found to be least remunerative treatment with the BC ratio of 1.72. The BC ratio was higher in 25 and 35 q ha$^{-1}$ targeted treatments without FYM when compared with same targeted treatments with FYM.Application of FYM increased the net returns and BC ratio in IPNS based STCR treatments over non-IPNS based STCR treatments. Almost similar results have also been reported by (Yadahalli*et al.*, 2014),(Singh *et al.*,2016)and (Choudhary and Dixit, 2022).

**Table 3. Effect of different fertilizers recommendations approaches on yield (q ha$^{-1}$) and profitability of wheat**

| Treatments | Grain yield (q ha$^{-1}$) | Stover yield (q ha$^{-1}$) | Net Returns (Rs ha$^{-1}$) | B:C Ratio |
|---|---|---|---|---|
| Control | 14.4$^{e}$ | 23.9$^{f}$ | 28695 | 2.57 |
| Farmers' practice | 16.5$^{de}$ | 27.2e$^{f}$ | 22528 | 1.72 |
| General recommended dose | 21.1$^{c}$ | 33.7$^{d}$ | 43204 | 2.77 |
| Soil test based | 22.9$^{c}$ | 36.3$^{cd}$ | 49374 | 3.07 |
| Target yield 25q ha$^{-1}$ | 25.5$^{b}$ | 39.8$^{bc}$ | 54703 | 3.08 |

| | | | | |
|---|---|---|---|---|
| Target yield 25q $ha^{-1}$ with FYM @ 5t $ha^{-1}$ | $26.8^{b}$ | $41.6^{b}$ | 48198 | 2.31 |
| Target yield 35q $ha^{-1}$ | $34.8^{a}$ | $51.1^{a}$ | 77695 | 3.58 |
| Target yield 35q $ha^{-1}$ with FYM @ 5t $ha^{-1}$ | $35.4^{a}$ | $53.0^{a}$ | 69649 | 2.70 |
| Beejamrit + Jeevamrit + Ghanajeevamrit | $16.9^{d}$ | $28.2^{e}$ | 28175 | 2.04 |

Values followed by different letter(s) differ significantly at $p<0.05$ as per Duncan's multiple range test (DMRT)

*Sale price of wheat, Grain= Rs 18.5 Rs $kg^{-1}$, Straw = Rs. 850 Rs $q^{-1}$; Jeevamrita=1.5(Rs $l^{-1}$), Beejamrita=2(Rs $l^{-1}$)*

*Cost of fertilizer (Rs $kg^{-1}$) N=11.9, $P_2O_5$ =65.8, $K_2O$ =28. FYM = Rs. 100 $q^{-1}$*

**Plant nutrients uptake**

**Macronutrients**

Data presented in fig. 1.indicatedsignificant variation in the nutrient uptake in wheat crop.A critical examination of the data revealed that the N, P and K uptake in wheat grain and straw was maximum under STCR based IPNS treatment for target yield of 35q $ha^{-1}$($T_8$) and minimum in control ($T_1$). N uptake in wheat grain and straw varied from 25.4 kg $ha^{-1}$ and 11.8 kg $ha^{-1}$under control ($T_1$) to 75.3 kg $ha^{-1}$ and 35.9 kg $ha^{-1}$under target yield 35 q $ha^{-1}$ with FYM @ 5 t $ha^{-1}$ ($T_8$), respectively. P uptake in wheat grain and straw varied from 4.04 kg $ha^{-1}$ and 2 kg $ha^{-1}$ in control ($T_1$) to 11.8 kg $ha^{-1}$ and 8.13 kg $ha^{-1}$ in target yield 35 q $ha^{-1}$ with FYM @ 5 t $ha^{-1}$ ($T_8$), respectively. K uptake in wheat grain and straw varied from 4.55 kg $ha^{-1}$ and 16.4 kg $ha^{-1}$ in control ($T_1$)to 14.6 kg ha-1 to 42 kg $ha^{-1}$in target yield 35 q $ha^{-1}$ with FYM @ 5 t $ha^{-1}$($T_8$),respectively. Supplementation of NPK fertilizers as per STCR approach with and without FYM significantly enhanced N, P and K uptake in wheat crop over general recommended dose,ZBNF treatment, farmers' practice and control.The significant increase in nitrogen, phosphorus and potassium uptake in grain and straw of wheat under STCR-IPNS treatments could be due to improved nutrient supplying capacity and flush of available nutrients.Simultaneous application of organic manure and chemical fertilizers results in the faster decomposition of chemical fertilizers compared to the organic manure, hence resulting in the increased nutrient availability to the plants. During the time of organic manure decomposition, many organic acids are released which break down the complex nitrogenous compounds gradually, providing a steady supply of nitrogen, phosphorus, and potassium throughout the crop growth period thereby, increasing wheat production and uptake of nutrients from soil system.

(Singh *et al.*,2020). Similar findings have been reported by (Choudhary and Dixit, 2022) and (Kumari *et al.*,2022) on wheat crop.

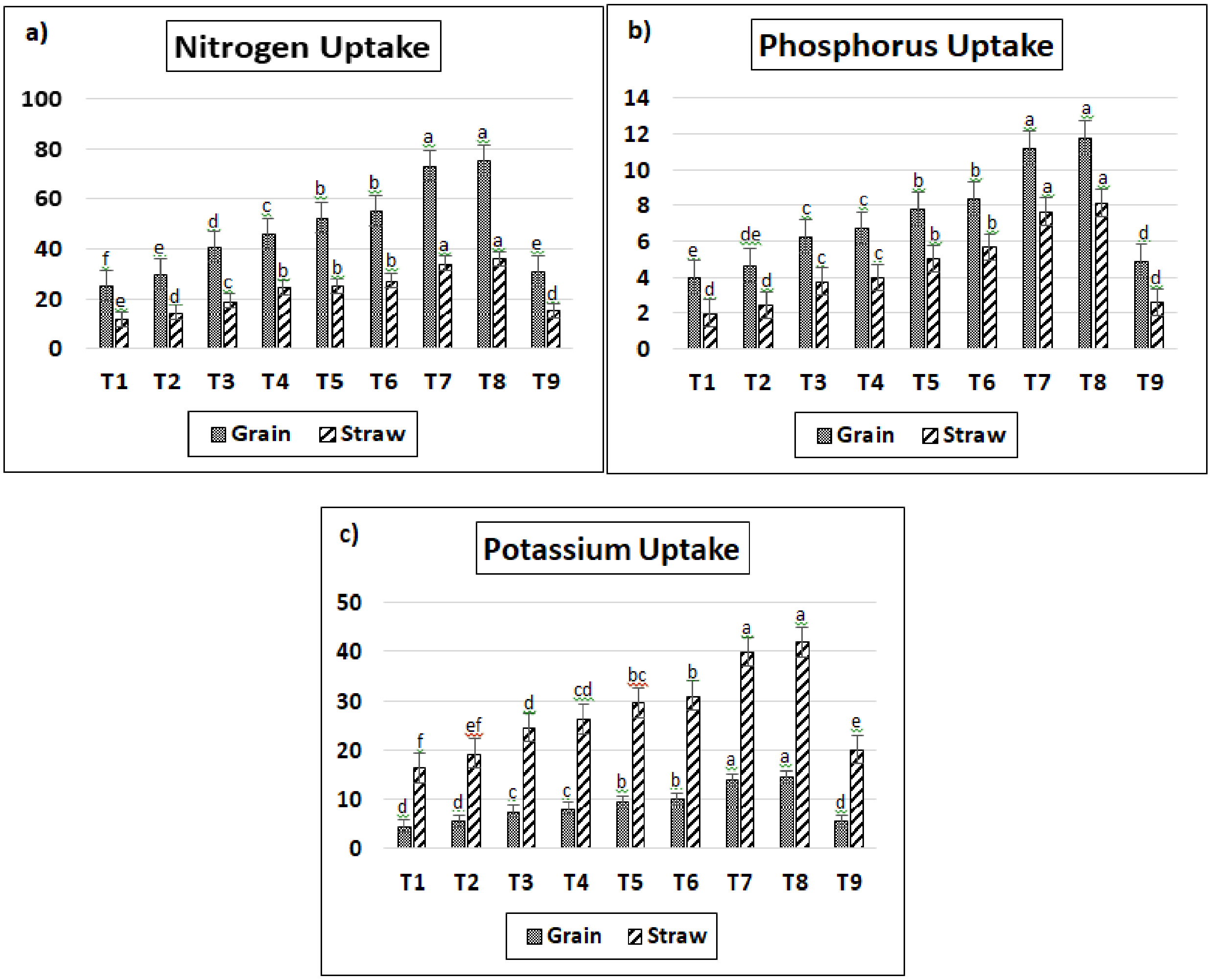


**Fig. 1. Effect of different recommendation of fertilizer application approaches on a) nitrogen, b) phosphorus and c) potassium uptake (kg ha$^{-1}$) by wheat.Bars with similar lowercase letters are not significantly different with respect to least significant difference (LSD) values at p=0.05**

**Micronutrients**

The results suggested that the different approaches of fertilizer application manifested a significant effect on the uptake of micronutrients by wheat over control (Fig. 2). The uptake of micronutrients was found to be maximum in the treatment target yield of 35 q ha$^{-1}$ with FYM ($T_8$) and minimum in control ($T_1$). All the STCR based target yield treatments with or without FYM were statistically superior over general recommended dose, ZBNF treatment, farmers' practice and control. Micronutrients uptake under treatments target yield of 25 q ha$^{-1}$ with 5 t ha$^{-1}$ FYM ($T_6$),target yield of 35 q ha$^{-1}$ ($T_7$) and target yield of 35 q ha$^{-1}$ with 5 t ha$^{-1}$ FYM ($T_8$) was statistically higher compared to soil test based ($T_4$).“FYM is a good source of nutrients and growth promoting substances and higher uptake of these micronutrients in treatments supplied with FYM might be attributed to higher content of these micronutrients present in FYM, presence of higher microbial and enzymatic activity which stimulated the root growth and resulted in higher uptake" (Laxminarayana and Patiram, 2006). "Moreover, addition of organic manures lowerthe soil pH due to the release of various acids upon its breakdown, which enhances the bioavailability of micronutrients compared to the sole use of inorganic fertilizers" (Dhaliwal *et al.*, 2023). Similar type of results were observed by(Nandapure*et al.*, 2011).

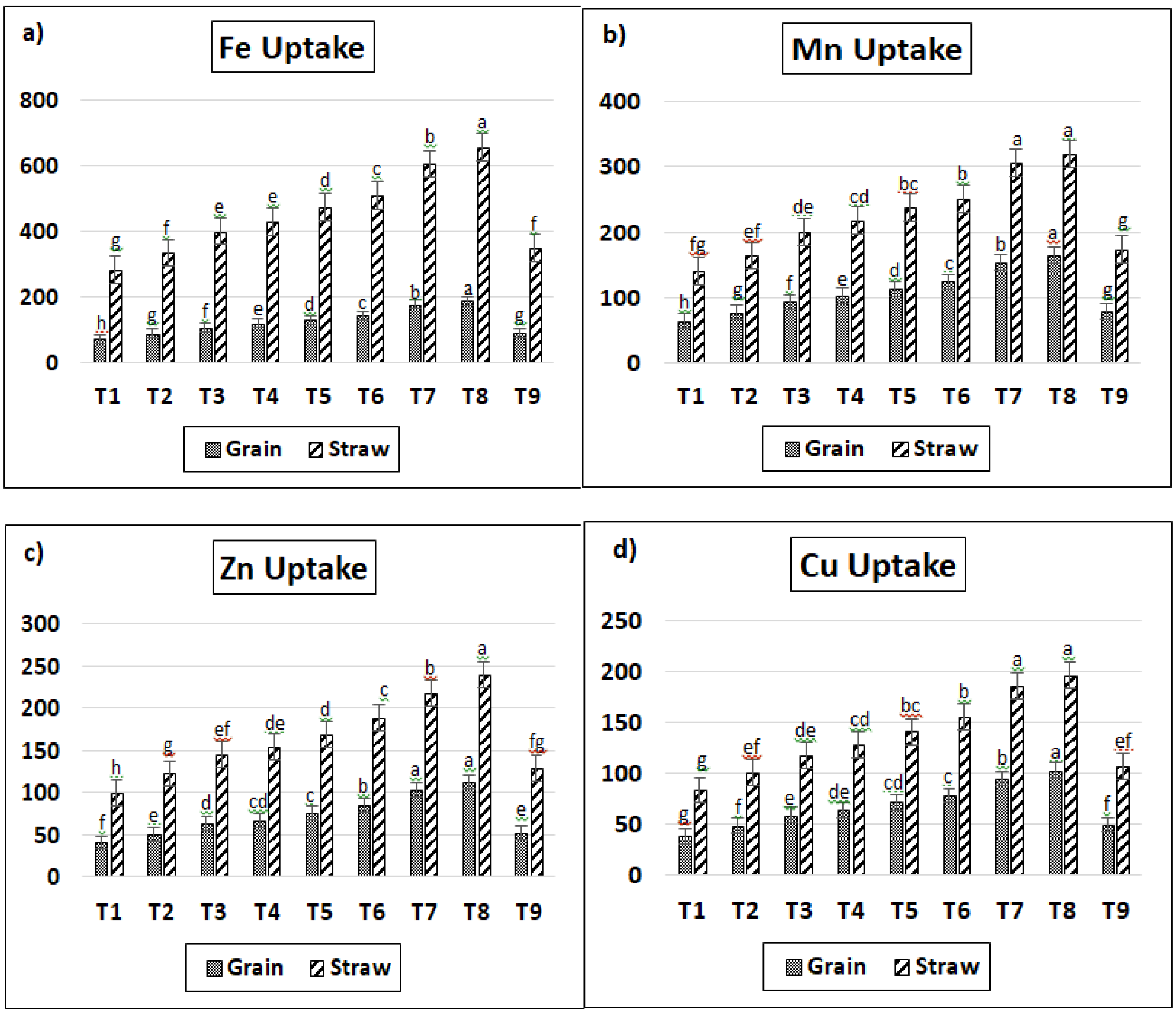


**Fig. 2. Effect of different recommendation of fertilizer application approaches on a) iron,b) manganese, c) zinc and d) copper uptake (g $ha^{-1}$) by wheat.Bars with similar lowercase letters are not significantly different with respect to least significant difference (LSD) values at p=0.05**

**Conclusion**

The findings of present study concluded that, the combined application of FYM and fertilizers under the STCR-based IPNS approach not only led to higher wheat yields but also resulted in the highest nutrients uptake in both wheat grains and straw.The STCR-based target yield approach maximizes economic yields by supplying nutrients precisely according to crop requirements, thereby enhancing fertilizer use efficiency and conserving expensive fertilizers. This approach can significantly benefit the resource-poor farmers by not only boosting yields but also reducing the cultivation costs.

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