***Original Research Article***

**Enhancing Wheat (*Triticum aestivum*) Productivity through Precision Nutrient Management in North Bihar, India**

**ABSTRACT**

An on-farm trial was conducted during the Rabi seasons of 2015-2016 and 2016-2017 at farmers’ field on pre-selected ten locations of Muzaffarpur district in North Bihar, considering farmers as replication, in order to assess the fertilizer application based on soil testing for the yield of wheat (Triticum aestivum) in North Bihar, India. The experimental field having average soil pH of 8.60, EC of 0.35 dSm-1, organic carbon of 0.63 percent, nitrogen of 221.33 kg ha-1, phosphorus of 51.71 kg ha-1 and potassium of 149.98 kg ha-1.The results revealed that nutrient management based on soil testing has a statistically significant impact on yield attributes, yield, and economics. The highest grain yield of 34.66 and 30.08 q ha-1 was found significantly in the soil test-based fertilizer application compared to the Recommended Dose of Fertilizer (RDF) (N120-P60-K40) and Farmers Practice (FP); (30.08 q ha⁻¹). The maximum net return (Rs. 27750 ha-1) and the B:C ratio (2.61) was found in the fertilizer application based on soil test relative to RDF (N120-P60-K40) and FP.

**Key words:** Crop, fertility, RDF, soil, wheat

**Introduction**

Wheat (Triticum aestivum L.) is an important agricultural crop growing throughout the world. It has been occupying largest area in the world among the cereals, contributing nearly 30% of the global cereal pool, in which India ranks second in the world, accounting for ~14% of global wheat production (Kumar *et al*., 2015). The average wheat productivity of India is 2.83 t ha-1. Over the past few decades, fertilizer consumption in India has increased appreciably (Kumar et al., 2024). In spite of that it is important to occurred the fertility statue found at a net negative nutrient balance of a staggering 8-10 million tons per year (Meena et al., 2024), which need to ensure the production around 15 million tons by 2025. Application of fertilizer nutrients by the farmer without knowing the soil fertility status and nutrient requirements of crop affects soil quality and production crops adversely (Ray et al., 2000; Kumar ., 2016). In India, during the past three decades, intensive agriculture involving exhaustive high-yielding varieties of rice and wheat uptake with heavy nutrients from the soil, where it requires more and more use of chemical inputs to feed the growing population (Singh *et al.,* 2021). The decline in soil fertility and growth productivity found imbalance in nutrient content, which is recognized as one of the most important factors that limits the crop yield (Singh *et al*., 2024; Singh *et al*., 2025). The continuous adopting intensive cropping and imbalanced fertilizer use are major causes of nutrient deficiency particularly N, P, K, and S (Singh *et al*., 2024a; Sinha et al., 2024). The fertilizer application at an appropriate time, and in a balanced proportion, followed appropriate technique has a positive impact on crop yield (Kumar *et al*., 2025). The targeted yield model’ is one of the practical approaches for efficient use of fertilizers was first given by Troug (1960), which was further modified by Ramamoorthy et al. (1967) as the ‘inductive-cum-targeted yield model. Soil test-based fertilizer recommendations for wheat crops can save the input cost, save the environment, and at the same time enhance the productivity of these crops (Kumar *et al.,* 2024). Keeping these facts in perspective, the present investigation was taken up to study the soil test-based fertilizer recommendation in the wheat (Triticum aestivum L.) crop of North Bihar. The objective of nutrient management strategies was to achieve the required crop yield in an efficient, economical, and sustainable manner. Soil fertility and other agronomic practices are crucial in determining the economic return and quality of wheat.

**Materials and Methods**

On-farm testing experiments were carried out during the Rabi seasons of 2015-16 and 2016-17 at Krishi Vigyan Kendra, Muzaffarpur (Bihar), on randomly pre-selected 10 farmers fields as replication, and each replication have plot size of 300 m². The study area is confined to the Muzaffarpur district that lies between 24054’ to 26023’ N latitudes and 84053’ to 85053’ E longitudes at 51.81 m above mean sea level (Figure 1) consisting Indo-Gangetic North-West Alluvial Plains of North Bihar, India (Kumar *et al*., 2024a). The study area contain tropical humid to sub-humid climate, with an average rainfall of 1234 mm, an average temperature of 25 to 30°C, and relative humidity of 67 percent. The nature of soil in experimental site was sandy loam to loam in texture, calcareous in nature (Singh et al, 2024). The experiment comprising three treatments includes viz. T0-farmers practice, T1-recommended dose of fertilizer (N120-P60-K40 kg ha-1) and T3- Soil Test-based fertilizer. Prior to laying out the trial, the initial soil samples were collected from each farmer’s field separately and analyzed for various chemical properties *viz.* available nitrogen by the alkaline potassium permanganate method (Subbiah and Asija, 1956); available phosphorus was extracted using the 0.5 MNaHCO₃extractable assess using spectrophotometer instrument (Olsen et al., 1954), similarly, available potassium was measured followed prescribed method (Jackson, 1973). The treatment were applied in equal marked plot as dose a full dose of phosphorus and potassium was applied as basal while nitrogen was applied in three splits, i.e. 50 percent basal and 25 percent each at crown root initiation and maximum tillering stage. Test crop ‘HD-2733’ was grown. The required observations like No. of effective tillers/sq m, Test weight, Grain yield, Straw yield, Biological yield and harvest Index (HI) were taken and data recorded during the experimental period were analyzed statistically in a randomized block design (RBD).

**Results and Discussion**

**Chemical properties of the soil**

***Soil pH and Soil electrical conductivity (EC)***

The soil pH is an important parameter which analyzed to help in the identification of the chemical nature of the soil reaction (Meena *et al*., 2023) as it measures hydrogen ion concentration in the soil to indicate its acidic and alkaline nature. The pH of the soil samples is presented in Table 1. The value of soil pH in experimental site ranged from 8.59 to 8.62 with the mean of 8.60, indicating throughout alkaline in nature. The electrical conductivity (dSm-1) of soil indicating the total soluble salts present in the soil depicting the salinity/alkalinity of soils. The lesser the EC value, showed the lower salinity value of the soil and vice- versa and the result showed that the EC of the study area ranged from 0.35 to 0.36 dSm-1with the mean of 0.35 dSm-1 showed the less affecting the crop growth. The finding is in conformity with the work of Kumar *et al*., 2021.

**Organic carbon (OC)**

Soil organic carbon is important properties not only in general influences the physico-chemical properties of soils but particularly affects the availability of nutrients, cation exchange capacity, soil structure, C:N ratio, and C:N:S ratio, etc., which are well recognized. Carbon is an indispensable necessity for soil fertility because it is strongly correlated with nitrogen and fuels the microbial engine that drives the nitrogen cycles (Kumar *et al*., 2024b). The OC of the soil samples ranged from 0.62 to 0.65% with a mean of 0.63% given in the Table 1.

**Available KMnO₄-N**, **Available Olsen-P,** and **Available** NH4**OAc-K**

The result for the available KMnO4-N presented in Table 1 shows that the distribution of the available KMnO4-N ranged from 217.00 to 225.50 kg N ha-1 with a mean of 221.33 kg N ha-1. The nitrogen falls under the low category range. Might be due to low decomposition of organic matter in the soil and lesser microbial activity (Kumar *et al*., 2024a). Phosphorus is the important element available in the biological systems which constitutes more than 1% of the dry organic weight. Affecting plant growth and found in soil both organic and inorganic forms (Kumar *et al*., 2014). The extractable available Olsen-P obtained in the study area, range from 50.67 to 52.75 kg P ha-1 with a mean value of 51.71 kg P ha-1 showed in Table 1. Soil from agricultural fields with a high range of available phosphorus content in the study area may be perhaps supplemented by applying phosphorus-rich fertilizers in high amounts as required for a specific crop (Kumar *et al*., 2024c). The data obtained for the available NH4OAc-K presented in Table 1 reveals distribution of the available potassium ranged from 144.08 to 155.93 kg ha-1 with the mean of 149.98 kg ha-1. It showed that the range of potassium amounted with medium range. Its availability can be enhanced by using the microbial inoculants as reported by Kumar *et al*., 2024d.

**Yield attributes and Yield**

The observation taken in terms of effective tillers and test weight of the wheat crop were improved significantly due to the application of soil test-based fertilizer over the rest of the treatments (Table 2).Whereas minimum values of the aforesaid character are associated with RDF, i.e., N120-P60-K40 and FP of experimentation. The yield and attributes of wheat were obtained investigation depicted in Table 2. The significantly higher grain, straw, and biological yield was recorded where nutrient used on soil test-based fertilizer method, which was found significantly superior to RDF and FP. The input used as integrated plant nutrient management has assumed great importance for soil productivity and boosting yield (Paswan et al., 2014; Sinha *et al*., 2024 Swarup, 2010). The soil test-based fertilizer application treatment recorded the highest harvest index (33.41%), while the lowest value was associated with FP (32.87%).

**Economics**

The economics of yield among all the treatments, maximum net return (Rs. 27750.00 ha-1) and B:C ratio in the treatment T3, however, minimum net return (Rs. 16000 ha-1) and B:C ratio were obtained with treatment T1 (Farmers Practice). The data reveals the markedly higher production recorded as because nutrient applied as soil test-based. Similar findings were recorded by Singh et al., 2017.

**Conclusion**

The present study highlights the significant benefits of soil test-based fertilizer (STBF) application in improving the yield and economic returns of wheat cultivation in North Bihar. The STBF treatment recorded the highest grain yield (34.66 q ha⁻¹), straw yield (68.51 q ha⁻¹), and biological yield (102.04 q ha⁻¹), which were significantly superior to both the recommended dose of fertilizer (RDF) and farmers' practice (FP). The highest net return (Rs. 27,750 ha⁻¹) and benefit-cost (B:C) ratio of 2.61 were also achieved under the STBF treatment, demonstrating its economic advantage. Soil test-based nutrient management ensured a balanced and efficient supply of nutrients, leading to improved nutrient use efficiency and enhanced crop performance. The practice of split nitrogen application at different growth stages further contributed to increased nutrient uptake and better crop response. The study confirms that soil test-based fertilizer application is not only effective in increasing wheat productivity but also in maintaining soil health and optimizing input costs. Therefore, adopting soil test-based nutrient management can serve as a sustainable strategy to enhance wheat production, improve farm profitability, and ensure long-term soil fertility.

**Recommendation:**

Based on the findings, it is recommended that farmers adopt soil test-based fertilizer (STBF) application methods as it has demonstrated higher grain yield (34.66 q ha⁻¹), straw yield (68.51 q ha⁻¹), and biological yield (102.04 q ha⁻¹) compared to the recommended dose of fertilizer (RDF) and farmers' practice (FP), ensuring a balanced nutrient supply and improved nutrient use efficiency. Organizing training programs and workshops to educate farmers on soil testing and balanced fertilization will enhance awareness and adoption. Developing region-specific fertilizer recommendations based on soil test results can further optimize nutrient use and increase productivity. Improving soil health through the incorporation of organic matter like compost and farmyard manure will enhance nutrient availability and soil structure. Encouraging split nitrogen application (50% at basal, 25% at crown root initiation, and 25% at maximum tillering stage) can improve nutrient uptake and crop performance. Regular monitoring and management of soil pH (mean 8.60) and EC (mean 0.35 dSm⁻¹) are essential to maintain soil health, with corrective measures like gypsum application where necessary. Since STBF recorded the highest net return (Rs. 27,750 ha⁻¹) and benefit-cost (B:C) ratio of 2.61, promoting this approach will not only increase productivity but also improve farmers' profitability. Policy support and subsidies for soil testing and balanced fertilization should be provided to encourage wider adoption of STBF practices, ensuring sustainable crop production and enhanced economic returns.

**Future scope of study:**

Future research should focus on evaluating the long-term impact of soil test-based fertilizer (STBF) application on soil health, nutrient balance, and microbial activity across multiple cropping cycles. Optimizing fertilizer doses for different wheat varieties, soil types, and environmental conditions will help enhance yield and nutrient use efficiency. Studies on the effect of STBF on the nutritional quality of wheat grains, including protein content and micronutrient composition, can provide valuable insights into improving food quality. Assessing the environmental benefits of STBF, such as reduced nutrient leaching, minimized soil degradation, and lower greenhouse gas emissions, will strengthen the case for sustainable farming practices. Integrating soil test-based recommendations with precision agriculture technologies like GPS mapping and remote sensing could improve targeted nutrient management. Economic feasibility studies at a larger scale, along with an analysis of adoption rates, will help identify barriers to implementation and suggest solutions. Research on crop rotation and diversification under STBF regimes can determine its adaptability across various cropping patterns. Developing decision support tools, such as mobile and web-based platforms, will enable farmers to receive real-time nutrient recommendations. Exploring the potential of combining organic and bio-fertilizers with soil test-based management can further enhance soil health and crop yield. Finally, participatory research involving farmers will provide ground-level feedback, helping to refine and improve STBF recommendations for better acceptance and implementation.

**Disclaimer (Artificial intelligence)**

**Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.**

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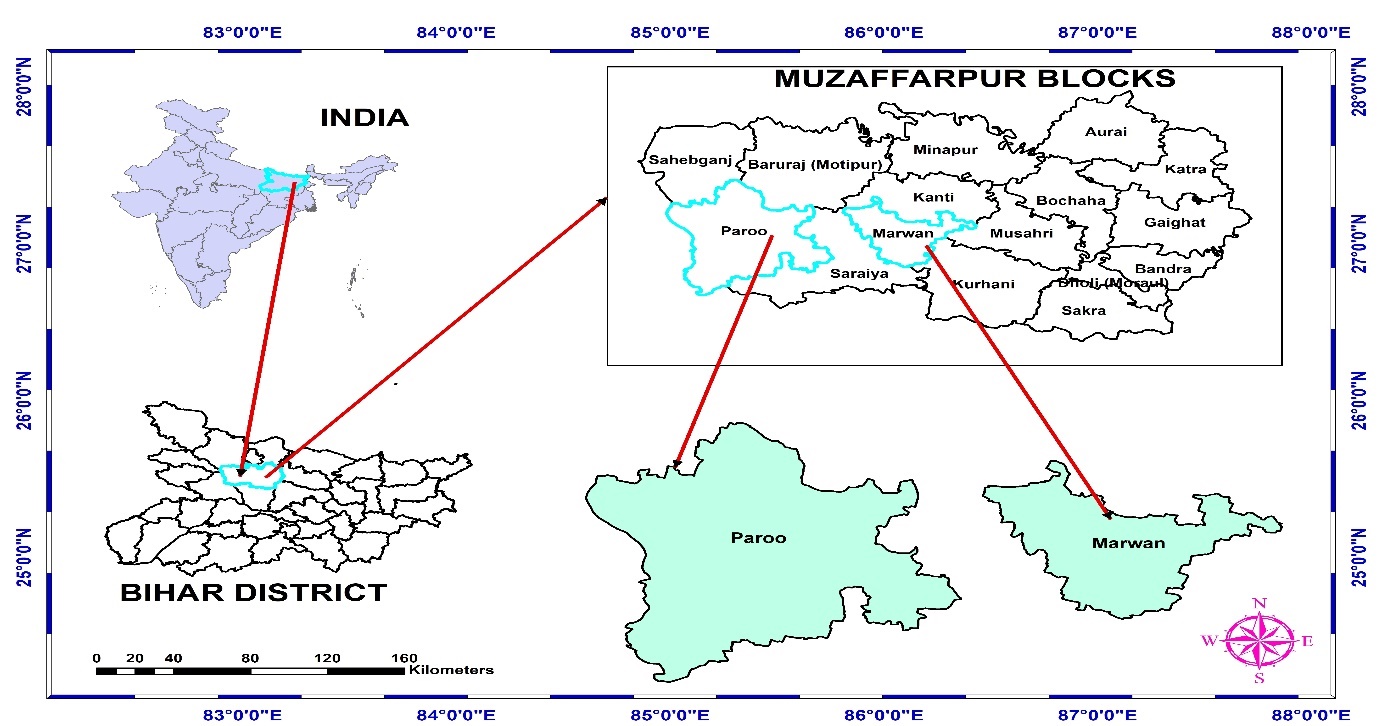
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**Fig.1 Location map of the study area in Muzaffarpur district of Bihar**

**Table1. Physico-chemical property and nutrient status of experimental soil (Pooled data of 2 years)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Nutrient status** | | | | | |
| **pH** | **EC**  **(dSm-1)** | **OC**  **(%)** | **KMnO4-N**  **(kg ha-1)** | **Olsen-P**  **(kg ha-1)** | **NH4OAc-K**  **(kg ha-1)** |
| **T0-FP** | 8.59 | 0.35 | 0.62 | 217.00 | 50.67 | 144.08 |
| **T1-RDF (N120:P60:K40)** | 8.60 | 0.35 | 0.63 | 220.50 | 51.70 | 149.93 |
| **T3-STBF** | 8.62 | 0.36 | 0.65 | 227.50 | 52.75 | 155.93 |
| **C D (P=0.05)** | NS | NS | NS | NS | NS | NS |
| **Mean** | 8.60 | 0.35 | 0.63 | 221.33 | 51.71 | 149.98 |

FP-Farmers practice, RDF-Recommended dose of fertilizer, STBF- Soil test based fertilizer

**Table 2 Effect of Soil test based fertilizer application on dry matter production (**Pooled data of 2 years)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Treatments** | **Yield attributes** | | **Yield q ha-1** | | | |
| **No. of effective tillers/sq m** | **Test wt. (100 grain wt.)** | **Grain yield** | **Straw yield** | **Biological yield** | **HI**  **(%)** |
| **FP** | 75.19 | 28.57 | 30.08 | 61.47 | 91.55 | 32.87 |
| **RDF (N120:P60:K40)** | 78.72 | 29.52 | 32.80 | 66.60 | 99.30 | 33.02 |
| **STBF** | 79.71 | 29.80 | 34.66 | 68.51 | 102.04 | 33.41 |
| **SEm** | 0.34 | 0.05 | 0.06 | 0.46 | 0.80 | 0.11 |
| **C D (P=0.05)** | 1.02 | 0.14 | 0.18 | 1.35 | 2.39 | 0.34 |

FP-Farmers practice, RDF-Recommended dose of fertilizer, STBF- Soil test based fertilizer

**Table 3 Effect of Soil test based fertilizer on economics (**Pooled data of 2 years)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatments** | **Cost of cultivation**  **(Rs. ha-1)** | **Gross return**  **(Rs. ha-1)** | **Net return**  **(Rs. ha-1)** | **B:C ratio** |
| **FP** | 17000.00 | 33000.00 | 16000.00 | 1.94 |
| **RDF (N120:P60:K40)** | 17500.00 | 41250.00 | 23750.00 | 2.34 |
| **STBF** | 18000.00 | 45750.00 | 27750.00 | 2.61 |
| **C D (P=0.05)** | NA | NA | NA | NA |