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Soil-Test-Based Fertilizer Prescription with Farmyard Manure for *Brassica juncea* on *Vertisols*: Assessing Nutrient Use Efficiency and Yield Response

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A B S T R A C T

This study evaluated the effects of STCR-based fertilizer prescriptions and farmyard manure (FYM) on yield, nutrient uptake, and overall nutrient use efficiency in mustard cultivated on Vertisols of Chhattisgarh. A factorial randomized block design with three replications comprising 16 treatments tracked the influence of targeted nutrient regimes (N, P, K) with or without FYM, including yield-target scenarios (14, 18, and 22 q/ha). Grain and straw yields responded positively to STCR-based fertilizer doses, with the highest realized yield of 21.79 q/ha under T8 (yield target 22 q/ha). Across yield targets, FYM generally enhanced nutrient use efficiency, though its effect on total nitrogen, phosphorus, and potassium uptake varied with the fertilizer regime. Nitrogen uptake was highest under the same STCR-based dose, while phosphorus and potassium uptakes followed similar trend lines, with T8 often yielding the peak total uptake. Interaction effects between FYM and fertilizer were largely non-significant, suggesting additive rather than synergistic interactions under the tested conditions. Omitting N markedly reduced yields and uptake, underscoring nitrogen's pivotal role in mustard productivity. The findings corroborate prior work on STCR-based nutrient prescriptions and highlight the viability of integrating inorganic fertilizers with organic amendments to stabilize yields, optimize nutrient uptake, and improve resource use efficiency in Vertisol-based systems. Implications for extension and policy emphasize adopting soil-test-guided nutrient management to meet targeted yield goals while mitigating input costs.

Keywords

Farmyard manure, Nutrient use efficiency, Vertisols, Integrated nutrient management, Soil test–based fertilization

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Introduction

Optimizing profitability from crops across diverse soil and climate conditions requires precise nutrient management: applying the right nutrient, in the right amount, through appropriate methods, at the right time. Soil test–based fertilizer recommendations offer a practical framework to balance nutrient supply with crop demand, enabling targeted, efficient fertilization. By aligning nutrient inputs with soil-available nutrients, this approach supports better crop performance while promoting sustainable soil health. The concept of optimizing fertilizer recommendations for specific yield targets emerged with Troug (1960), and was subsequently refined by Ramamoorthy *et al.,* (1967). The targeted yield model that evolved from these foundations relies on the fertility gradient field experimental approach—a comprehensive framework for fertilizer management aimed at achieving predefined yield goals. This method integrates soil test values with the crop's nutrient requirements and accounts for the nutrient contributions from soil, fertilizers, and manures, enabling precise calibration of fertilizer applications to fixed yield targets.

A definite quantity of nutrients is required to achieve a pre-determined crop yield. Nutrient requirements can be estimated by integrating the contributions from native soil-available nutrients with those supplied through targeted fertilizer applications (Subba Rao & Srivastava, 2001). This nutrient-balance approach underpins precise nutrient management by quantifying the nutrient supply from the soil pool and the expected incremental supply from fertilizers to meet the crop's physiological demand toward the targeted yield. The identification of a nutrient deficiency relies on soil-based diagnostics to guide targeted nutrient applications. Correcting soil nutrient imbalances through balanced fertilization can enhance nutrient use efficiency and promote synergistic interactions among nutrients, thereby optimizing crop response (Rao & Srivastava, 2000). The higher response ratio and benefit–cost ratio can be achieved through soil-test–based nutrient applications delivered in a targeted proportion. Balanced fertilization encompasses not only applying the right quantity of fertilizers for crop growth but also optimizing the timing, method, and sources of nutrient delivery. Nutrient management strategies increasingly integrate chemical fertilizers with organic manures and biofertilizers to sustain soil health and resource use efficiency. The anticipated crop yield response to nutrient input is essential for formulating fertilizer recommendations and is determined by the crop's nutrient requirements, the availability of nutrients from indigenous soil pools, and the fate of the applied fertilizer (Dobermann *et al.,* 2003). Rising fertilizer costs underscore the need for alternative nutrient supply strategies that leverage farmers' available resources. The use of organic amendments and other locally available inputs can enhance soil properties, improve nutrient recovery, and boost crop productivity and biological activity. Although crops may have substantial genetic potential, its realization is often limited by low nutrient-use efficiency associated with imbalanced chemical fertilizer practices. Soil-test–based fertilizer recommendations remain a popular and practical approach among farmers, given its suitability for achieving balanced fertilization tailored to soil conditions and crop needs. The targeted yield approach underpins balanced crop nutrient management by optimizing the use of available resources. Soil testing provides a reliable assessment of fertility status and informs fertilizer requirements aligned with defined yield goals or maximum economic return. A fertilizer prescription framework serves as a practical tool for need-based nutrient applications. Within this approach, recommendations can be tailored to individual fields, targeting specific yield objectives based on soil-test results and the local availability of fertilizer inputs. Soil-test–based fertilizer applications help prevent both over- and under-application of nutrients, thereby improving nutrient-use efficiency, crop yield, and long-term soil fertility. Among oilseed crops, rapeseed and mustard (Brassica spp.) rank as a globally important group, following soybean and palm oil. In India, rapeseed–mustard accounts for a substantial share of edible oilseed production, contributing around 28.6% of the total oilseeds produced among seven edible oilseed crops. It is the second most important oilseed crop after groundnut, representing approximately 27.8% of India's edible oilseed sector. Rapeseed–mustard occupies about 3% of the total cropped area, out of roughly 14.1% devoted to oilseeds in the country. The group includes crops such as Indian mustard, yellow sarson, brown sarson, raya, and toria. Indian mustard (Brassica juncea L. Czern & Cosson) is predominantly cultivated in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat, with expansion into parts of South India such as Andhra Pradesh, Tamil Nadu, and Karnataka, including non-traditional areas. Rapeseed and mustard can be grown under both irrigated and rainfed regimes. Fertilizer consumption in India rose from about 89.8 thousand tonnes in 1950–51 to 25.53 million tonnes in 2012–2013 (Agricultural Statistics at a Glance, 2014). With a growing population and increasing demand for grain, per-capita fertilizer use is likely to rise further, underscoring the need for efficient nutrient management to sustain crop productivity. To sustain soil fertility and maximize yield, nutrient applications must be carefully managed. A crop's high-yield potential is realized only when the soil provides an adequate and well-balanced supply of nutrients. The soil's nutrient-supplying capacity is increasingly constrained by continuous intensive cultivation and rising nutrient demands. This decline in productivity is largely attributed to imbalanced fertilization and rising fertilizer costs. Consequently, precise and prudent nutrient management is essential to maintain soil fertility and achieve optimal yields. Soil testing is widely recognized as a cornerstone of judicious fertilizer use, helping to prevent under- or over-application and to ensure balanced nutrient supply aligned with crop needs.

Material and Methods

Study Area

Raipur, the capital of Chhattisgarh, is located near the center of the state (approximately 21°16′ N, 81°60′ E) at an average elevation of 289.6 meters above mean sea level. The IGKV Instructional Farm lies in the eastern part of Raipur, adjacent to National Highway 6, at approximately 20°04′ N, 81°39′ E, with an altitude of about 293 meters above mean sea level.

Soil Characteristics

The soil employed in the study was analyzed for key physical and chemical properties. The texture comprised 26.4% sand, 28.8% silt, and 44.8% clay, indicating a clay-dominant soil. The soil water-holding capacity was 39.48%, with porosity of 41.32%. The pH was measured at 7.4, indicating a near-neutral soil environment, and the electrical conductivity (EC) was 0.18 dS m^{-1}, reflecting low to moderate soluble salt content.

Experimental details

The experiment was conducted using a factorial randomized block design (FRBD) with three replications. The trial comprised 16 treatment combinations, including a set of control and nutrient management options with and without farmyard manure (FYM).

Method of Plant Analysis

Dried straw and grain were grinded and used for following chemical analysis Nitrogen content was determined by KEL plus unit methods as described by Chapman and Pratt, (1961). Phosphorus in the diacid extract of plant samples was estimated by vanadomolybdo phosphoric yellow colour method using spectrophotometer at 420nm wave length as described by Jackson (1973). Potassium in the diacid extract of plant samples was determined using flame photometer as per the method described by Jackson (1973).

Statistical Analysis

All field and laboratory observations were recorded systematically and organized for analysis. The experiment was laid out as a factorial randomized block design (FRBD) with appropriate replication. Data were subjected to analysis of variance to assess treatment effects. When the F-test indicated significant effects, mean comparisons were performed using the standard error of the mean (SEM) and critical difference (CD) at the 5% probability level.

Results and Discussion

Yield response of grain and straw to targeted fertilizer applications

The results presented in Fig. 3.1 indicate that grain and straw yields of mustard were significantly influenced by fertilizer and farmyard manure (FYM) applications, while the interaction between these factors (F ×T) was non-significant. Grain yield reached its maximum with the STCR-based dose (yield target of 22 q/ha), corresponding to 21.79 q/ha in treatment T8, followed by T5 (N_{120} P_{60} K_{40}), T7 (yield target 18 q/ha), and T3 (N_{120} P_0 K_{40}). The inclusion of FYM significantly increased grain yield compared with sole inorganic fertilization, underscoring the benefits of integrated nutrient management. Potassium application also had a discernible effect on grain yield, with a notable difference between T2 (N_{120} P_{60} K_0) and T5 (N_{120} P60 K40). Straw yield followed a pattern similar to grain yield and was significantly improved by fertilizer and FYM treatments, with the highest straw yield observed in T8 (yield target 22 q/ha) under the STCR-based fertilization regime. Omitting nitrogen (as in T4: N_0 P_{60} K_{40}) markedly reduced both grain and straw yields, highlighting the critical role of N for mustard production. Across treatments, FYM consistently enhanced both grain and straw yields compared with plots receiving no FYM, likely due to improved nutrient availability and uptake efficiency.

The STCR-based fertilizer applications aimed at target yields of 14, 18, and 22 q/ha produced grain yields of 14.20, 18.15, and 21.79 q/ha, respectively. The observed yields were within ±10% of the prescribed targets, whether fertilizers were applied alone or in combination with farmyard manure, indicating the reliability of soil-test-based prescriptions under the experimental conditions. These results support the validity of soil-test–based fertilizer prescription equations for mustard grown on Vertisols in Chhattisgarh. The findings are in general agreement with earlier work by Sonar *et al.,* (1982), Dev *et al.,* (1985), and Milapchand *et al.,* (1984), which similarly reported successful alignment between prescribed nutrient regimes and realized yields, underscoring the potential of targeted nutrient management to achieve defined yield goals.

Nutrients uptake

Nitrogen uptake

Fig. 3.2 show that nitrogen uptake in grain, straw, and total N uptake by mustard was significantly influenced by fertilizer application, whereas the interaction between fertilizer and FYM (FT) was not statistically significant. Since N uptake depends on both nitrogen content and dry matter, the observed patterns for grain, straw, and total N uptake were largely congruent. The highest N uptake in grain, straw, and total was recorded under T8, which received the STCR-based fertilizer dose to achieve a yield target of 22 q/ha. Incorporation of FYM did not produce significant differences in N uptake compared with plots receiving only inorganic fertilizers. The mean total N uptake was highest under T8 (yield target 22 q/ha), showing a significant advantage over all other treatments. Treatment T5 ($N_{120}P_{60}K_{40}$) did not differ significantly from T7 (yield target 18.0 q/ha), suggesting similar N-availability and crop uptake under those regimes. The observed increase in available nitrogen from applied fertilizer likely enhanced canopy photosynthesis and biomass accumulation, contributing to higher N uptake and crop yield. Conversely, the omission of nitrogen resulted in markedly reduced N uptake and yield, underscoring the critical role of N in mustard productivity. The strong yield responses associated with higher N input align with findings from other studies reporting pronounced crop responses at elevated N levels (Bhandari & Gautam, 2013; Pranab, 2010).

Phosphorus uptake

Fig. 3.3 show that phosphorus uptake in grain, straw, and total P uptake by mustard was significantly influenced by fertilizer application, while farmyard manure (FYM) and the interaction between FYM and fertilizer (FT) were not statistically significant. The total P uptake was highest under T8 (yield target 22 q/ha) at 21.94 kg ha^{-1}, followed by T5 (N_{120} P_{60} K_{40}) and T7 (yield target 18.0 q/ha); however, the difference between T5 and T7 was not significant. Total P uptake in T2 and T3 did not differ significantly, even with and without P application.

Phosphorus uptake in grain exhibited a pattern similar to the total P uptake, while straw P uptake was highest in T8, with other treatments showing no consistent trend. FYM application did not produce significant differences in P uptake. A similar response pattern was reported by Ahmed *et al.,* (2015).

Potassium uptake

Fig. 3.4 show that total potassium uptake by mustard was significantly influenced by fertilizer treatments, while farmyard manure (FYM) and the interaction between FYM and fertilizer (FT) were not significant. The highest total K uptake occurred with T8 (yield target 22 q/ha), followed by T7 and T5; the difference between T5 and T7 was not significant, and T2 and T3 did not differ significantly from each other despite differences in K application. FYM application did not significantly alter potassium uptake compared with sole inorganic fertilization. Across plant parts, potassium uptake was greater in the straw than in the grain. The observed patterns are consistent with reports from Bhandari & Gautam (2013), Ahmed *et al.,* (2015), and Pranab (2010).

The study demonstrates that STCR-based fertilizer prescriptions, with or without farmyard manure (FYM), can effectively steer mustard production toward predefined yield targets on Vertisols in Chhattisgarh. Across yield targets, yield attainment was closest to the prescribed goals under the STCR-based dose (notably at 22 q/ha), with grain and straw yields reaching 21.79 q/ha and corresponding total nutrient uptake patterns supporting this outcome. FYM generally enhanced nutrient use efficiency and crop response, although its impact on individual nutrient uptake was contingent on the underlying fertilizer regime, indicating additive rather than synergistic effects under the tested conditions. Interaction effects between FYM and inorganic fertilizer were largely non-significant, suggesting that the benefits of organic amendments may be context-dependent and best realized as part of an integrated nutrient management strategy rather than as a universal modifier.

Fig.1 Total N uptake of mustard

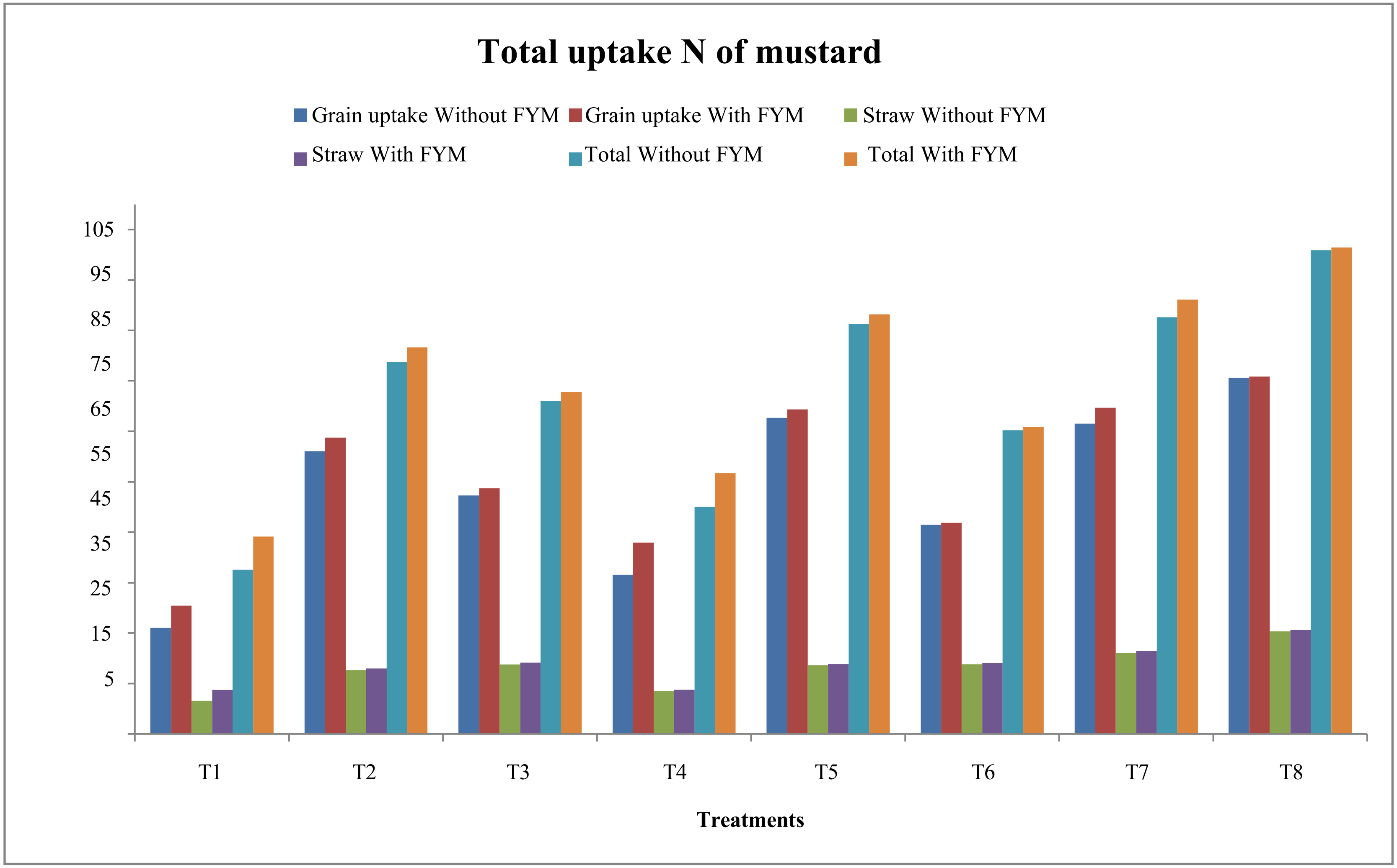


Fig.2 Total P uptake of mustard

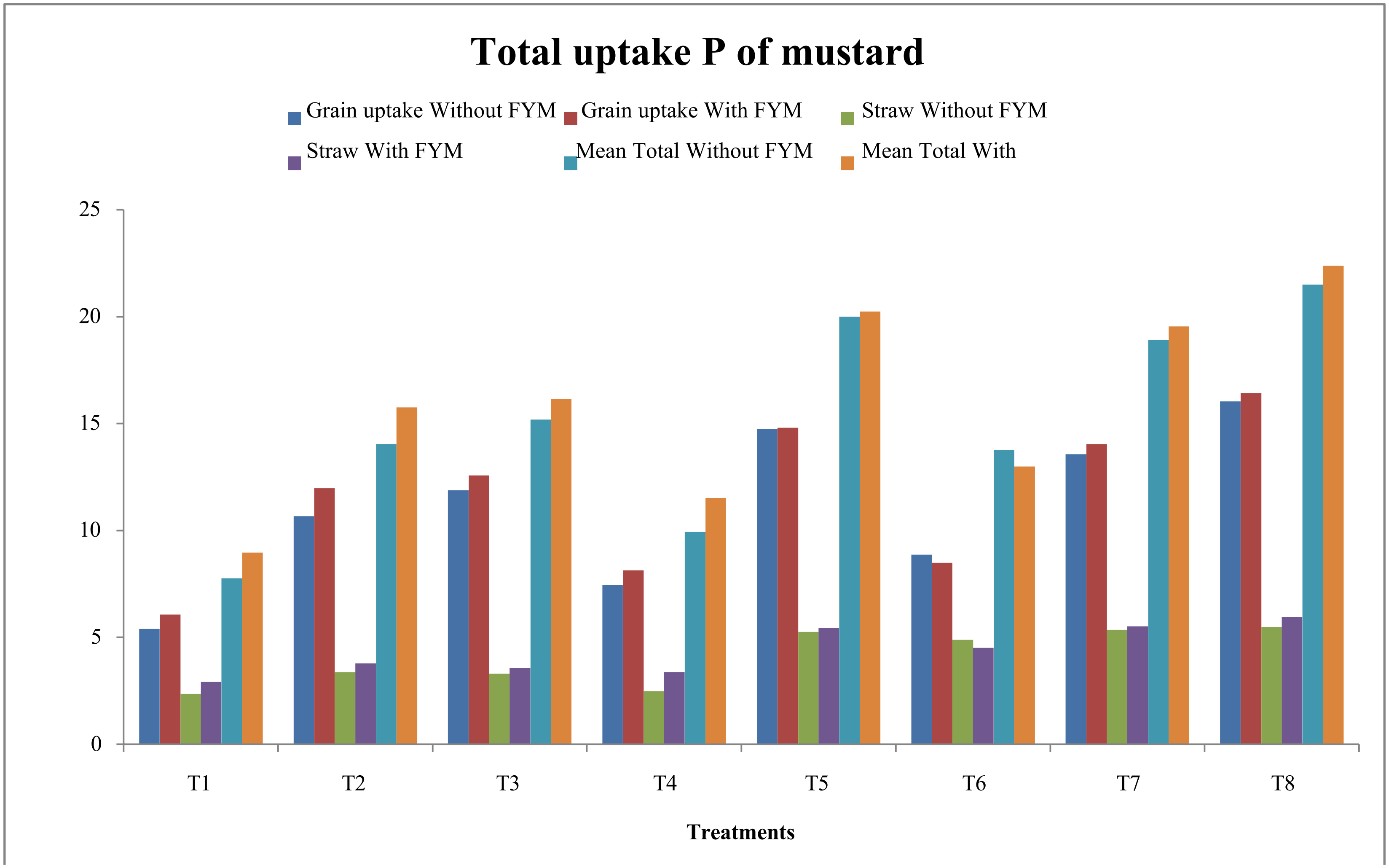


Fig.3 Total K uptake of mustard

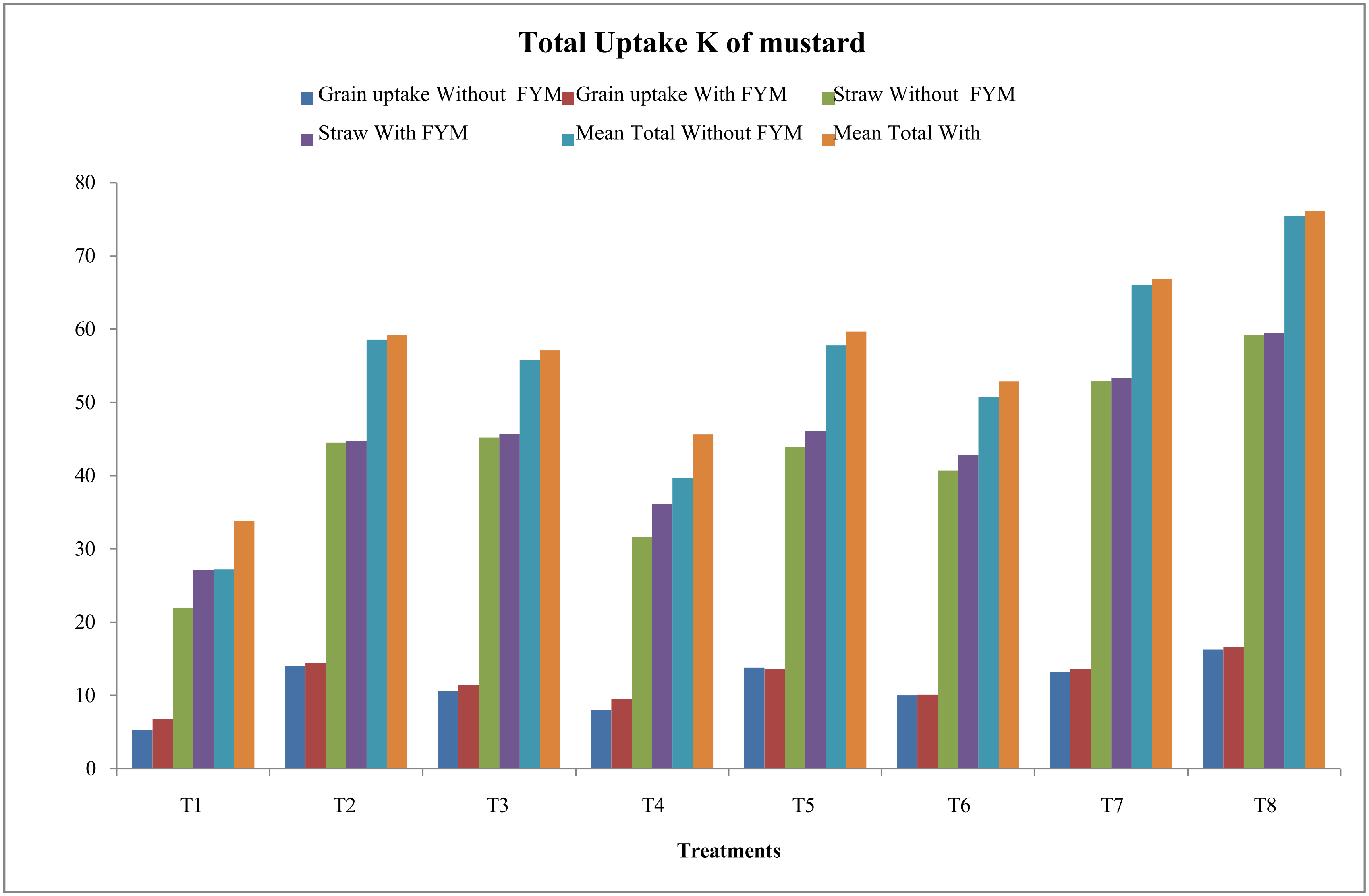
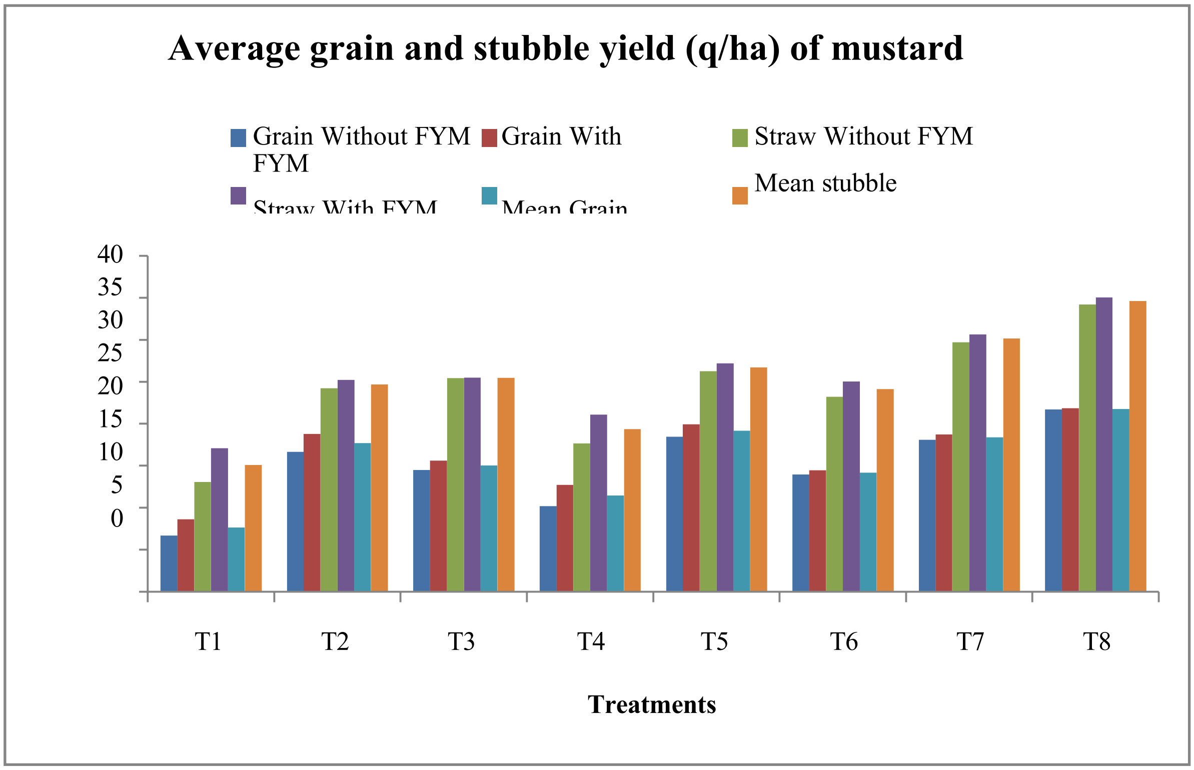


Fig.4 Average grain and straw yield (q/ha) of mustard



The omission of nitrogen markedly reduced both yield and nutrient uptake, reaffirming N as a critical limiting factor for mustard productivity in this system.

Collectively, these results corroborate the viability of soil-test-based fertilizer prescriptions for achieving targeted yields while optimizing nutrient uptake and resource use efficiency, with practical implications for cost-effective nutrient management, extension guidance, and policy formulation in Vertisol-dominated agroecosystems. Future work should explore long-term effects, economic analyses, and regional adaptations to further refine recommendations for farmers.

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Author Contributions

Onkar Singh: formal analysis, methodology, writing– original draft; Lalit Kumar Srivastava: conceptualization, data curation, formal analysis, methodology, writing – original draft. Anusuiya Panda: formal analysis, data curation, methodology, writing – original draft, Vinay Bachkaiya: formal analysis, writing – original draft;

Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this manuscript.

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent to Participate

Not applicable.

Consent to Publish

Not applicable.

Conflict of Interest

The authors declare no competing interests.

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