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# Soil Test Crop Response Concerning Soil Properties and Yield Attributes of Mustard (*Brassica juncea* L.) *var.* Krishna

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

We experimented in the field at the central research farm of the Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj during *Rabi* season of 2022-23. The soil in the experimental area was characterized by a sandy loam texture. There were 27unit plots in total, with each plot sized at 2 X 2 m. We used a randomized block design, incorporating different levels of NPK (80:40:40), vermicompost, and two levels of sulfur (50% and 100%). The $T_9$ (STCR+ 5t $ha^{-1}$ Vermicompost+ 100% S) demonstrated that although there was a slight decrease in pH, bulk density, and particle density, there was a significant ($P<0.05$) increase in pore space, water holding capacity, electrical conductivity (EC),

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organic carbon, and the availability of nitrogen, phosphorus, and potassium. Improvements were observed in plant growth and yield attributes, which showed the best results in terms of plant height, number of siliquae per plant, and total mustard yield compared to the control conditions. However, the use of organic manures and their combination with a full NPK treatment significantly enhanced the growth and overall yield attributes of mustard.

*Keywords: NPK; nitrogen; phosphorus; potassium; sulphur; vermicompost.*

## 1. INTRODUCTION

"Soil, whether deep or shallow, red or black, sandy or clayey, serves as the crucial link between the rocky core of Earth and the living organisms on its surface. It provides the foundation for the plants we cultivate, which is the primary reason for our interest in soil," remarked Simonson [1]. Soil quality is pivotal for ensuring sufficient food production for a sustainable life, influenced by various factors such as climate, topography, and parent material, according to James [2].

The targeted yield model represents a practical method for the efficient utilization of fertilizers. Initially proposed by Troug [3] and later refined by Ramamoorthy et al*.* [4] as "the Inductive-cum targeted yield model, this approach combines the use of inorganic and organic nutrients through site-specific integrated nutrient management (SSINM) to achieve balanced fertilization. This method incorporates the soil test crop response (STCR) strategy, which is critical for prescribing precise fertilizer doses to achieve desired crop yields".

"Mustard (*Brassica juncea* L.), ranks as the world's third largest oilseed crop, following soybeans and palm oil, accounting for 28.6% of India's total oilseed production" [5]. "Ranking second only to groundnut in India's edible oilseed sector, mustard is cultivated primarily in Rajasthan, Uttar Pradesh, Haryana, Punjab, and Madhya Pradesh. This versatile crop produces not only seeds but also edible leaves, stems, and roots, serving as a significant source of food and fodder. Despite its importance, India's average mustard yield of 1190 kg/ha is well below that of industrialized nations (2500-3000 kg/ha) and the global average of approximately 1900 kg/ha" [6-10].

Sulphur is viewed as the fourth major plant nutrient, following nitrogen, phosphorus, and potassium. It plays a vital role in enhancing the uptake of phosphorus and is essential for the synthesis of nitrogen in proteins [11,12]. Sulphur is crucial for producing key amino acids such as cysteine and methionine and participates in various metabolic processes within plants, including being a component of glutathione—a compound linked to plant respiration and essential oil synthesis [13-15,7]. It also significantly contributes to chlorophyll formation. Various factors, including depleted soil nutrients from continuous cropping, lead to reduced crop yields. Restoring soil fertility is essential for sustaining and improving crop yields, and can be effectively achieved through integrated nutrient management. However, the lack of knowledge regarding the methods and timing of manure and fertilizer application has led to increased cultivation costs [16,17]. Maintaining soil fertility requires a thorough understanding of soil nutrient status, fertilizer effectiveness, and the appropriate times and methods for applying fertilizers [18,19].

The Soil Test Crop Response (STCR) model, suggested by Ramamoorthy et al*.,* provides a method to determine balanced and efficient fertilizer applications based on soil test values to optimize crop yield. Utilizing the STCR approach to determine plant nutrient needs has notably enhanced both crop yields and soil health, crucial for sustainable yields and reducing fertilizer expenses. Adopting the STCR methodology in Chhattisgarh could lower cultivation costs and promote intelligent, strategic nutrient management [20,21,22]. The targeted yield strategy posits a linear relationship between a crop's grain yield (economic output) and its nutrient uptake. This model adeptly balances "fertilizing the crop" with "fertilizing the soil," making it adaptable to specific field conditions. It also provides a dependable method for estimating regional fertilizer needs to reach certain crop production goals [22,23]. By fine-tuning fertilizer application and yield targets, We aimed to maximize profitability from fertilizer investments while maintaining soil health. The targeted yield method has been widely employed to develop fertilizer recommendations nationwide.

## 2. MATERIALS AND METHODS

During the *Rabi* season of 2022-23, a mustard experiment involving three distinct factors was initiated at the central experimental farm of the Department of Soil Science and Agricultural Chemistry at Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj. The area is situated on the South of Prayagraj - Rewa National Highway 27, and is nearly 6 Km away from Prayagraj city. It is located at a latitude of 25°24'23" N and a longitude of 81°50'38" E, with an altitude of 98 m above minimum sea level. The experiment was organized using a randomized block design and included three replications. There were 27 unit plots in total, with each plot sized at 2 X 2 m. The irrigation layout consisted of a main channel that was 1 m wide and sub-irrigation channels were 0.5 m wide. According to the World Reference Base classification (FAO, 2014), the soil of the experimental farm is Inceptisol, with a sandy loam texture. Nutrient management practices were T1- Absolute Control, T2- RDF +5t $ha^{-1}$ Vermicompost + 50 % S, T3- STL + 5t $ha^{-1}$ Vermicompost +50 % S, T4- FP+ 5t $ha^{-1}$ Vermicompost +50% S, T5- STCR + 5t $ha^{-1}$ Vermicompost +50% S, T6- RDF 100% + 5t $ha^{-1}$ Vermicompost + 100% S, T7- STL 100% + 5t $ha^{-1}$ Vermicompost + 100 % S, T8- FP +5t $ha^{-1}$ Vermicompost + 100%S, T9- STCR+ 5t $ha^{-1}$ Vermicompost+ 100% S. where, RDF- Recommended dose of fertilizers (80:40:40 kg $ha^{-1}$), STL- Soil Test Levels (80:28:28 kg $ha^{-1}$), FP- Farmer's Practice (50:30:30 kg $ha^{-1}$), STCR- Soil Test Crop Response (40:15:15 kg $ha^{-1}$). All experimental plants were subjected to the same cultural techniques during the study, which included applying fertilizer, watering, filling in gaps, earthing up, controlling weeds, haulm pruning, and taking precautions against damage to the plants. Soil samples were collected from each plot at a depth of 0-15 cm at various stages of the experiment, then air-dried, finely ground, and sieved through a 2 mm mesh before storage in polythene bags. These stored samples were analyzed for a range of physico-chemical properties and changes in available nutrients such as nitrogen, phosphorus, potassium, sulfur, and % organic carbon content. Analyses conducted on the soil included bulk density, particle density, % pore space, soil texture, pH, and levels of available N, P, K, and S.

## 2.1 Treatments of the Investigation

STCR approach: For Mustard, the STCR equation that follows was utilized to reach the 25 quintal per hectare yield target.

With Vermicompost

1. Nitrogen (kg $ha^{-1}$) -12.27T-0.56SN-0.09V C-N
2. Phosphorus (kg $ha^{-1}$) 4.60T-3.29SP-0.06VC-P
3. Potassium (kg $ha^{-1}$) =4.69T-0.24K-0.05VC-K

Where, T= Yield target (q $ha^{-1}$), SN= Alkaline $KMnO_4$-N, SP= Olsen's P (kg $ha^{-1}$) and Sk + Amm. Ac.- K (kg $ha^{-1}$).

The equations for adjusting fertilizer requirements were prepared to determine the necessary amounts for achieving specific yield targets in mustard, such as 25 quintals per hectare, with variations based on soil test values. The findings indicate that the amount of fertilizer needed varies depending on the soil test results for a given yield target. A similar result was also shown by Mishra et al. and Singh et al. [24]

## 2.2 Nutrient Requirement

a) N Kg required per quintal of seed production = $\frac{Total\ uptake\ of\ N\ (kg\ ha^{-1})}{Seed\ yield\ (q\ ha^{-1})}$

b) P Kg required per quintal of seed production = $\frac{Total\ uptake\ of\ P\ (kg\ ha^{-1})}{Seed\ yield\ (q\ ha^{-1})}$

c) K Kg required per quintal of seed production = $\frac{Total\ uptake\ of\ K\ (kg\ ha^{-1})}{Seed\ yield\ (q\ ha^{-1})}$

## 2.3 Plant Content and Nutrient Uptake Analysis

When grain samples were taken from each treatment at harvest, the chemical analysis of the plants was carried out to determine the nutrient content, including the concentrations of nitrogen, phosphorous, potassium and sulphur concentration (%) and their uptake (kg $ha^{-1}$). The plant material was oven-dried, ground, and analyzed using specific methods: nitrogen by micro-Kjeldahl, phosphorus by the vanado-molybdo phosphoric acid method, potassium via flame photometry, and sulfur through the Turbidometric Method. Nutrient uptake was calculated using established formulas based on the concentration and dry weight of the plant material.

$$\text{Nutrient uptake } (N, P, K \text{ kg ha}^{-1}) = \frac{\text{Nutient content in grain } (\%) \times \text{Yield } (\text{kg ha}^{-1})}{100}$$

### 2.4 Nutrient Response Ratio (kg yield kg nutrient $^{-1}$)

The calculation was performed using the following equation provided by the Indian Society of Agronomy, New Delhi.

$$NRR = \frac{Yield(kg)}{Amount\ of\ nutient\ applied\ (kg)}$$

## 3. RESULTS AND DISCUSSION

### 3.1 Physical Properties of Soil

The data in Table 1 reveals that there were no significant changes in the bulk and particle density of the soil across various fertilizer recommendation levels based on soil test values. The highest bulk density (1.303 Mg $m^{-3}$) and particle density (2.535 Mg $m^{-3}$) were observed in treatment T1, while the lowest bulk density (1.281 Mg $m^{-3}$) and particle density (2.510 Mg $m^{-3}$) were noted in treatment T9. These results are consistent with findings reported by Nagar et al. and Sahu et al*.* Conversely, significant differences were observed in soil pore space and water retaining capacity (WRC) at different fertilizer levels. The maximum soil pore space (49.06%) and WRC (46.79%) were recorded in treatment T9, with the minimum values (48.54% pore space and 45.25% WRC) in treatment T1. These outcomes align with studies by Ahmadi and David,[25] and Alam et al*.*[26]

### 3.2 Chemical Properties of Soil

Table 2 illustrates that increasing fertilizer levels as recommended by soil tests significantly enhances the availability of nutrients such as nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) in the soil. The highest levels of available nutrients - N (271.13 Kg ha^-1), P (22.73 Kg $ha^{-1}$), K (210.3 Kg $ha^{-1}$), and S (18.47 Kg $ha^{-1}$) - were recorded in treatment T9. Conversely, the lowest levels - N (233.15 Kg $ha^{-1}$), P (22.14 Kg $ha^{-1}$), K (189.7 Kg $ha^{-1}$), and S (11.20 Kg $ha^{-1}$) - were observed in treatment T1. These results are consistent with findings from previous research by Upadhyay et al[27]*.,* Rajput et al*.,*[28] and P. Dey [29].

### 3.3 Seed Yield (q $ha^{-1}$)

Table 3 shows a significant increase in mustard seed yield correlating with higher amounts of fertilizer prescribed based on soil test readings. The maximum seed yield, reaching 11.53 q $ha^{-1}$, was recorded in treatment T9, while the minimum yield of 7.33 q $ha^{-1}$ was observed in treatment T1. The findings of the current investigation are also consistent with those of Kumar et al [7]. and Pal and Pathak. [30]

### 3.4 Plant Nutrient Concentration

A detailed analysis of the data present in Table 4 indicates that the concentrations of nutrients such as nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) in the grain significantly increased with higher levels of fertilizer application, as recommended based on soil test values. The highest nutrient concentrations - N (1.73%), P (0.23%), K (1.47%), and S (3.9%) were observed in treatment T9, which was notably higher than in any other treatment combination. In contrast, the lowest concentrations - N (1.05%), P (0.14%), K (1.08%), and S (2.83%) - were recorded in treatment T1. These findings are consistent with previous research by Bharose et al*.*[31] and Chaurasia et al*.*[32]

**Table 1. Response of Vermicompost and inorganic fertilizers based on STCR of mustard on physical properties of soil after crop harvest**

| Treatment | Bulk Density (Mg $m^{-3}$) | Particle Density (Mg $m^{-3}$) | Pore space (%) | WRC (%) |
|---|---|---|---|---|
| $T_1$ | 1.30 | 2.53 | 48.54 | 45.25 |
| $T_2$ | 1.30 | 2.53 | 48.57 | 45.38 |
| $T_3$ | 1.29 | 2.52 | 48.67 | 45.43 |
| $T_4$ | 1.29 | 2.52 | 48.71 | 45.53 |
| $T_5$ | 1.29 | 2.52 | 48.67 | 45.83 |
| $T_6$ | 1.29 | 2.52 | 48.83 | 46.32 |
| $T_7$ | 1.28 | 2.52 | 48.94 | 46.73 |
| $T_8$ | 1.28 | 2.51 | 48.02 | 46.74 |
| $T_9$ | 1.28 | 2.51 | 49.06 | 46.79 |

| Treatment | Bulk Density (Mg $m^{-3}$) | Particle Density (Mg $m^{-3}$) | Pore space (%) | WRC (%) |
|---|---|---|---|---|
| F-test | NS | NS | S | S |
| S.Em. (±) | 0.01728 | 0.04261 | 0.88487 | 0.21578 |
| C.D. (P= 0.05) | 0.05202 | 0.12828 | 2.66372 | 0.70139 |

**Table 2. Response of Vermicompost and inorganic fertilizers based on STCR of mustard on Chemical Properties of soil after crop harvest**

| Treatment | Available Nitrogen (kg $ha^{-1}$) | Available Phosphorous (kg $ha^{-1}$) | Available Potassium (kg $ha^{-1}$) | Available Sulphur (Kg $ha^{-1}$) |
|---|---|---|---|---|
| $T_1$ | 233.15 | 22.14 | 189.7 | 11.20 |
| $T_2$ | 236.33 | 22.63 | 198.6 | 13.73 |
| $T_3$ | 243.35 | 22.46 | 202.0 | 13.97 |
| $T_4$ | 249.44 | 22.71 | 203.0 | 14.40 |
| $T_5$ | 250.31 | 22.78 | 205.3 | 14.54 |
| $T_6$ | 258.40 | 22.49 | 205.6 | 17.40 |
| $T_7$ | 262.20 | 22.56 | 206.7 | 17.87 |
| $T_8$ | 264.42 | 22.60 | 209.0 | 18.23 |
| $T_9$ | 271.13 | 22.73 | 210.3 | 18.47 |
| **F-test** | **S** | **S** | **S** | **S** |
| S.Em. (±) | 4.62058 | 1.05795 | 4.79221 | 0.15423 |
| C.D. (P= 0.05) | 9.83537 | 0.49702 | 10.2007 | 3.19254 |

**Table 3. Response of Vermicompost and inorganic fertilizers based on STCR of mustard on Chemical Properties of mustard after crop harvest**

| Treatment | Seed Yield (q $ha^{-1}$) |
|---|---|
| $T_1$ | 7.33 |
| $T_2$ | 9.47 |
| $T_3$ | 9.50 |
| $T_4$ | 9.53 |
| $T_5$ | 9.53 |
| $T_6$ | 9.67 |
| $T_7$ | 9.70 |
| $T_8$ | 11.13 |
| $T_9$ | 11.53 |
| F-test | S |
| S.Em. (±) | 0.394 |
| C.D. (P= 0.05) | 1.284 |

**Table 4. Response of Vermicompost and inorganic fertilizers based on STCR of mustard on concentration of Nitrogen (%), Phosphorus (%), Potassium (%) and Sulphur (%) of Grain**

| Treatment | N% | P% | K% | S% |
|---|---|---|---|---|
| $T_1$ | 1.05 | 0.14 | 1.08 | 2.83 |
| $T_2$ | 1.14 | 0.15 | 1.11 | 3.01 |
| $T_3$ | 1.17 | 0.16 | 1.15 | 3.10 |
| $T_4$ | 1.40 | 0.17 | 1.17 | 3.24 |
| $T_5$ | 1.50 | 0.18 | 1.21 | 3.35 |
| $T_6$ | 1.53 | 0.18 | 1.26 | 3.45 |
| $T_7$ | 1.57 | 0.19 | 1.32 | 3.52 |
| $T_8$ | 1.61 | 0.21 | 1.39 | 3.64 |
| $T_9$ | 1.73 | 0.23 | 1.47 | 4.02 |

| Treatment | N% | P% | K% | S% |
|---|---|---|---|---|
| **F-test** | **S** | **S** | **S** | **S** |
| S.Em. (±) | 0.08 | 0.01 | 0.06 | 0.14 |
| C.D. (P=0.05) | 0.25 | 0.03 | 0.19 | 0.21 |

**Table 5. Response of Vermicompost and inorganic fertilizers based on STCR of mustard on the nutrient response ratio (kg kg$^{-1}$) at 90 DAS**

| Treatment | Nitrogen Response ratio (kg kg$^{-1}$) | Phosphorous Response ratio (kg kg$^{-1}$) | Potassium Response ratio (kg kg$^{-1}$) | Total Response ratio (kg kg$^{-1}$) |
|---|---|---|---|---|
| $T_1$ | - | - | - | - |
| $T_2$ | 30.82 | 48.74 | 48.74 | 146.22 |
| $T_3$ | 30.83 | 61.65 | 61.65 | 154.13 |
| $T_4$ | 31.08 | 62.17 | 62.17 | 155.42 |
| $T_5$ | 31.45 | 83.10 | 83.11 | 206.96 |
| $T_6$ | 48.74 | 88.07 | 88.07 | 211.15 |
| $T_7$ | 49.86 | 88.86 | 88.85 | 216.06 |
| $T_8$ | 66.65 | 89.85 | 89.85 | 244.37 |
| $T_9$ | 68.90 | 103.73 | 103.73 | 336.36 |
| **F-test** | | | **S** | |
| S.Em. (±) | | | 16.62 | |
| C.D. (P=0.05) | | | 35.23 | |

### 3.6 Nutrient Response Ratio (kg kg$^{-1}$)

The data in Table 5 clearly shows that the nutrient response ratio (kg kg$^{-1}$) significantly increased with the elevation of fertilizer recommendation levels, as determined by soil test values. The highest total nutrient response ratio was observed in treatment T9, recording 336.36 kg kg$^{-1}$, while the lowest was noted in treatment T1, at 146.22 kg kg$^{-1}$. Similar findings were reported by Yadav et al*.* (2017), Singh et al*.* (2017).

## 4. CONCLUSION

The application of Vermicompost and inorganic fertilizers in T9 was found best in increasing the growth and yield of mustard. The findings from this study suggest that the Soil Test Crop Response (STCR) based Integrated Nutrient Management (INM) approach not only boosts mustard crop yields but also substantially enhances the nutrient content and absorption in the plants, contributing to nutrient enrichment in mustard seeds. The results underscore the effectiveness of the STCR-IPNM strategy in sustaining soil health. It is recommended that the STCR-IPNM method be utilized as an effective tool for balanced fertilization in agricultural practices.

## 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 writing or editing of manuscripts.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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