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# Optimizing Fenugreek Yield through Tailored Potassium Fertilizer Rates

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## ABSTRACT

This research aims to enhance fenugreek (Trigonella foenum-graecum) yield by systematically exploring the impact of various potassium fertilizer rates. Employing application rates of 0, 30, 60, 90, and 120 kg $ha^{-1}$, the study investigates the optimal potassium dosage for maximizing fenugreek productivity. The experiment spans multiple growing seasons to account for potential variations in environmental conditions. Throughout the research, key agronomic parameters such as plant height, leaf area, flowering patterns, and seed yield are meticulously monitored and analyzed. By employing a randomized complete block design, the study ensures statistical rigour in assessing the response of fenugreek to different potassium levels. The comprehensive data generated will contribute valuable insights into the crop's nutrient requirements and the nuanced relationship between potassium fertilizer rates and fenugreek yield. The findings of this research hold significant implications for agricultural practices, providing farmers and agronomists with evidence-based recommendations for optimizing fenugreek production through tailored potassium fertilizer application. Ultimately, the study seeks to contribute to sustainable and efficient agricultural practices, aligning with the broader goals of improving crop yield and food security in a dynamically changing agricultural landscape.

## Introduction

Fenugreek (Trigonella foenum-graecum) holds a unique position in global agriculture as a versatile and economically significant crop with diverse applications, ranging from culinary use to medicinal properties [1,2]. Its seeds are rich in various bioactive compounds, including alkaloids, flavonoids, and saponins, making fenugreek an essential component in traditional medicine and a sought-after spice in various cuisines [3]. As the demand for fenugreek continues to rise, optimizing its yield becomes paramount to meet the growing global needs [4].

One key factor influencing crop productivity is the judicious application of essential nutrients, and potassium stands out as a critical element in this context [5]. Potassium plays a pivotal role in numerous physiological processes within plants, including enzyme activation, osmoregulation, and the regulation of stomatal conductance. As a result, its availability profoundly impacts plant growth, development, and ultimately, yield [6,7,8,9]. Despite the acknowledged importance of potassium, the optimal application rates for fenugreek cultivation remain a subject of considerable debate and variability [10,11]. The optimization of fenugreek yield has far-reaching implications, both economically and nutritionally. Fenugreek seeds, in addition to their culinary significance, are known for their potential health benefits, including antidiabetic, antioxidant, and anti-inflammatory properties. As such, enhancing fenugreek productivity through tailored potassium fertilization not only addresses the economic concerns of farmers but also contributes to broader public health and nutrition goals.

The previous research seeks to address this issue by undertaking a systematic and comprehensive investigation into the impact of tailored potassium fertilizer rates on fenugreek yield. They employs a range of potassium application rates, to discern the nuanced response of fenugreek plants to varying potassium levels. The global agricultural landscape is evolving rapidly, with climate change, soil degradation, and increasing demand for sustainable practices necessitating a reevaluation of traditional farming approaches. In this context, optimizing nutrient management practices is essential not only for maximizing crop yield but also for ensuring the long-term sustainability of agricultural systems. Our research aligns with this imperative, contributing valuable insights into the specific potassium requirements of fenugreek and offering a foundation for informed and sustainable agronomic practices.

This investigation into optimizing fenugreek yield through tailored potassium fertilizer rates is situated at the intersection of agricultural science, sustainability, and public health. By elucidating the nuanced relationship between potassium application rates and fenugreek productivity, we aspire to provide evidence-based recommendations that can empower farmers and agronomists to enhance crop yield while promoting sustainable and resilient agricultural practices.

## Materials and Methods

1. **Study Site and Experimental Design:** The research was conducted at AZRC DI Khan, representative of the typical fenugreek-growing region. The experiment employed a randomized complete block design, with each treatment replicated thrice to account for variability in the field.

2. **Fenugreek Cultivation:** Fenugreek seeds were sown following local agronomic practices. The crop was cultivated in rows with a standardized inter-row and intra-row spacing. Standard cultural practices, including irrigation, pest control, and weed management, were implemented uniformly across all experimental plots.

3. **Potassium Fertilizer Application:** Potassium fertilizer ($K_2O$) was applied at five different rates: 0, 30, 60, 90, and 120 kg $ha^{-1}$. The potassium source used was [Specify Potassium Source]. The application was carried out at specific growth stages, including germination, vegetative growth, and flowering, to simulate the dynamic nutrient demands of the fenugreek crop.

4. **Soil Sampling and Analysis:** Soil samples were collected before the initiation of the experiment to determine the baseline soil fertility. Post-harvest soil samples were also collected to assess nutrient dynamics. Soil analyses included pH, organic matter content, and nutrient concentrations, with a focus on potassium levels.

5. **Agronomic Parameters:** Various agronomic parameters were measured throughout the growing season. These included plant height, leaf area, flowering onset, and duration. Harvesting was conducted at maturity, and fenugreek seeds were collected for yield determination.

6. **Statistical Analysis:** Collected data were subjected to statistical analysis using appropriate software (MSTAT). Analysis of Variance (ANOVA) was performed to assess the significance of differences among treatment

means. Post-hoc tests, such as Tukey's HSD, were employed for pairwise comparisons.

## Results

### 1. Soil Analysis:

The initial soil analysis revealed a pH of 7.9, an organic matter content of 0.78%, and a baseline potassium concentration of 39.8 ppm. Post-harvest soil analysis demonstrated variations in potassium levels across different fertilizer treatments, confirming the effectiveness of the applied potassium rates in Table 1.

**Table 1: Effect of potassium application at different rates on potassium contents of soil**

| Potassium Rates Kg $ha^{-1}$ | Soil Potassium Mg $kg^{-1}$ |
|---|---|
| 0 | 37.65 |
| 30 | 43.2 |
| 60 | 49.46 |
| 90 | 57.89 |
| 120 | 67.42 |

### 2. Agronomic Parameters:

### a. Plant Height:

Plant height exhibited a dose-dependent response to potassium application. Results indicated a significant increase ($p < 0.05$) in plant height with higher potassium rates. The tallest plants were observed in the 120 kg $ha^{-1}$ treatment, suggesting a positive correlation between potassium availability and vertical growth.

### b. Leaf Area:

Analysis of leaf area demonstrated a similar trend, with a noticeable increment in leaf area as potassium rates increased. This phenomenon aligns with potassium's role in promoting cell expansion and turgor pressure, contributing to enhanced leaf development.

### c. Flowering Patterns:

Potassium fertilization influenced flowering onset and duration. The 60 and 90 kg $ha^{-1}$ treatments exhibited the most synchronized and prolonged flowering periods. The 120 kg $ha^{-1}$ treatment, while promoting vigorous vegetative growth, showed a slight delay in flowering, suggesting a potential trade-off between vegetative and reproductive growth at higher potassium levels.

### d. Seed Yield:

The ultimate measure of the experiment's success was seed yield. Results demonstrated a significant increase in fenugreek seed yield with potassium application, peaking at the 90 kg $ha^{-1}$ treatment. Beyond this rate, a diminishing return was observed, indicating an optimal potassium range for maximizing seed production.

| Potassium Rates Kg $ha^{-1}$ | Plant Height (cm) | Leaf Area ($cm^2$) | Flowering time (cm) | Seed Yield (Kg $ha^{-1}$) |
|---|---|---|---|---|
| 0 | 21.42 | 9.02 | 68.13 | 103.52 |
| 30 | 29.87 | 11.31 | 71.28 | 133.48 |
| 60 | 33.13 | 12.22 | 67.23 | 168.73 |
| 90 | 39.24 | 14.99 | 65.13 | 215.59 |
| 120 | 46.63 | 16.81 | 79.01 | 171.29 |

## Discussion

The observed positive correlation between potassium rates and plant height and leaf area underscores the crucial role of potassium in promoting cell elongation and expansion [7]. The increased turgor pressure resulting from optimal potassium levels likely contributed to enhanced vegetative growth [9]. The nuanced impact on flowering patterns suggests that while potassium is essential for reproductive development, an excess might lead to a delay in flowering [9,11]. This observation prompts further investigation into the intricate hormonal and physiological mechanisms governing fenugreek's response to potassium during different growth stages. The substantial increase in seed yield up to the 90 kg $ha^{-1}$ treatment highlights the significance of precision in nutrient management. This optimal range not only maximizes yield but also minimizes the environmental and economic costs associated with excess fertilizer application [12]. The findings of this study have direct implications for sustainable agricultural practices. Tailoring potassium fertilizer rates to the specific needs of fenugreek not only enhances yield but also

promotes resource-use efficiency and minimizes the ecological footprint of cultivation [13]. To build upon these results, future research should delve deeper into the molecular and physiological mechanisms underlying fenugreek's response to potassium. Additionally, field trials across diverse agroecological zones will provide a more comprehensive understanding of the generalizability of these findings.

## Conclusion

This research establishes a clear link between tailored potassium fertilizer rates and enhanced fenugreek yield. The systematic investigation revealed a dose-dependent response in agronomic parameters, with optimal results observed at the 90 kg $ha^{-1}$ potassium application rate. Beyond this threshold, diminishing returns were evident, emphasizing the need for precision in nutrient management. These findings contribute valuable insights to fenugreek cultivation practices, offering a balance between maximizing yield and minimizing environmental impact. The study underscores the importance of sustainable agricultural practices, aligning with global efforts to optimize resource use. As fenugreek holds economic and nutritional significance, the tailored approach to potassium fertilization demonstrated in this research is poised to positively impact both farmers' livelihoods and broader food security initiatives. Future research should explore the molecular mechanisms governing fenugreek's response to potassium for a more comprehensive understanding.

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