Chemical Science Review and Letters ISSN 2278-6783

www.chesci.com Research Article

Response of Phosphorous and Zinc on Growth, Yield and Quality of Fenugreek (*Trigonella Foenum Graecum* L.)

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Abstract

A field experiment was conducted at Research farm, Vivekananda Global University, Jaipur (Rajasthan) during Rabi season, 2025-26 on loamy sand soil. The experiment comprises four levels for Basal application of phosphorus (0, 20, 40 and 60 kg ha^{-1}) and three treatments of zinc applied as foliar spray (Water Spray, 0.5% spray at 40 Days stage, 0.5 % spray at 40 and 60 days stage) thereby making 12 treatment combinations was laid out in factorial randomized block design and replicated thrice. Results showed that application of 60 kg P_2O_5 ha^{-1} as basal application significantly increased the plant height, dry matter accumulation, pods/plant, seeds/pod, length of pods test weight and seed and straw yields of fenugreek. Results further indicated that plant height, dry matter accumulation, pods/plant, seeds/pod, length of pods test weight, seed and straw yields and B:C ratio significantly increased with foliar application of zinc at 40and 60 days stage in comparison to other treatments. Seed yield was significantly and positively correlated with number of pods/plant, seeds/pod, test weight and uptake of N, P and Zn.

Keywords: Zinc, Nutrient content, Uptake Foliar spray, Phosphorus

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Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is one of the oldest cultivated medicinal and culinary plants belonging to the family Fabaceae. It is widely grown in India, the Mediterranean region, North Africa, and parts of Asia for its seeds and leaves, which have both nutritional and therapeutic importance. The name “fenugreek” is derived from the Latin term foenum-graecum, meaning “Greek hay,” indicating its ancient use as a forage crop. In India, it is commonly known as methi [1]. In Indian culinary tradition, fenugreek seeds are an indispensable spice used in pickles, curry powders, and other dishes, while the leaves (methi saag) are consumed as a green leafy vegetable. Over centuries, the plant has transitioned from being a local household remedy to a globally recognized medicinal herb. The seeds contain a rich mixture of nutrients and phytochemicals. They are high in proteins (23–26%), dietary fiber (approximately 48%), and essential minerals like iron, magnesium, calcium, and phosphorus. The bitter taste of the seeds is primarily due to the alkaloid trigonelline and steroidal saponins, while diosgenin, a precursor for synthetic steroid hormones, is one of its most economically valuable components [2]. Fenugreek is well adapted to semi-arid and temperate climates, requiring relatively cool growing conditions. It grows best in loamy to sandy soils with good drainage. As a legume, it has the ability to fix atmospheric nitrogen through symbiosis with Rhizobium bacteria, making it a soil-enriching crop often included in crop rotations. Omission of P resulted in 8.9 and 11.4% reduction in maize and wheat grain yield, respectively. This proves that P application plays an instrumental role in enhancing the yield of crop. Moreover, Zinc is a crucial micronutrient that plays a fundamental role in crop production. It regulates plant growth, reproduction, stress resistance, and product quality. Deficiency of zinc leads to stunted growth, reduced yields, and poor nutritional value of crops.

Material and Methods

The experiment was conducted at Research farm, Vivekananda Global University, Jaipur during Rabi season 2025-26. Geographically, this place is situated at 750 47’ East longitude, 260 51’ North latitude and at altitude of 390 m above mean sea level in Jaipur district of Rajasthan. This region falls under Agro-climatic zone IIIa (Semi-arid eastern plain zone) of Rajasthan. The climate of this place is semi-arid characterized by aridity of the atmosphere and extremity of temperature both in summer (45.5 ºC) and winter (4ºC). The average rainfall of this region is between 500-700 mm per

annum which is mostly received during July to September. The sporadic showers in winters are also common. There was rainfall of 25.60 mm during the crop season 2025, respectively during the crop period. In order to evaluate the physico-chemical properties, soil samples from 30 cm depth were taken from five random spots of the experimental field prior to layout and representative composite sample was prepared by mixing and processing of all soil samples together. The homogeneous composite soil sample was subjected to mechanical, physical and chemical analysis. The experimental soil was loamy sand, alkaline in reaction, poor in organic carbon, and low in available nitrogen. The available zinc content of the soil was 0.48 mg kg^{-1}, which is below the critical limit of 0.6 mg kg^{-1} (DTPA-extractable Zn), indicating zinc deficiency and justifying the use of foliar zinc application.

Results and Discussion

Effect of Basal application of Phosphorus on growth attributes

All growth attributes, *viz*. plant height and drymatter accumulation were increased significantly with the soil application of Phosphorus during the year of experiment. Results showed that, all the treatments exhibited significant variations to each other except treatment of 40 kg P_2O_5 ha^{-1} that was found statistically at par with 60 kg P_2O_5 ha^{-1}. However, at 60 DAS and at maturity during experiment tallest plant observed with the application of 60 kg P_2O_5 ha^{-1} with a respective value (35.34 and 46.83 cm) which found at par with the application of 40 kg P_2O_5 ha^{-1} in the tune of plant height (34.87 and 45.90 cm). Dry-matter accumulation/plant was positively correlated with plant height however highest dry matter (4.94 and 7.94 g $plant^{-1}$) which found at par with the application of 40 kg P_2O_5 ha^{-1} in the tune of plant dry matter (4.68 and 7.68 g $plant^{-1}$) at all the stages of the observations. Since P helps in cell-division, its adequate availability owing to increasing level resulted in increased inter-nodal length leading to increased plant height and leaf area. Increased leaf area during periodic stages as evident from significantly higher LAI, probably resulted in more interception of solar radiation. In addition, P is noted especially for its role in capturing and converting the Sun's energy into useful plant compounds leading to formation of greater amount of photosynthates and consequently accumulating more dry matter. Tang *et al*. (2001) [3] reported that, by 35 days after transplanting (DAT), the number of nodules tended to increase with increasing P supply and the nitrogenase activity per unit nodule mass doubled when the external P concentration was increased. Similarly P fertilization with bio-inoculants increased the growth, yield, and yield attributes of pigeon-pea under Indo Gangetic Plains of India [4].

Effect of basal application of phosphorus yield attributes

A perusal of data **Table 1** indicated that the Pods/plant, pod length, seeds/pod, test weight, seed and biological yield/ha improved significantly up to soil application of 60 kg P_2O_5 ha^{-1} in during the year of investigation. However, all the Phosphorus treatments significantly improved the yield attributes and yields over the control. Application of 60 kg P_2O_5 ha^{-1} resulted in the highest yield attributes and yield, followed by 40 kg P_2O_5 ha^{-1}. Application of 40 kg P_2O_5 ha^{-1} when applied, was also effective over the control and were statistically at par with each other, for pods/plant, pod length, test weight, seed and straw yield/ha. Activation of metabolic processes through P application and its role in building phospholipids and nucleic acid is known. Thus, the favourable stimulatory effect of P under sufficient P supply that on nodulation, production of assimilates and their efficient partitioning into different sinks significantly improved the yield attributes *viz*. pods/plant, seeds/pod, test weight, and ultimately the seed and straw yields. Our results confirm the findings of Kumawat *et al.* (2021) [5]. Sharma *et al.* (2014) [6] reported positive impacts of P fertilizers on fenugreek yield.

Effect of basal application of phosphorus on economics.

After statistical analysis of data it was concluded that the application of different treatments of Phosphorus application in fenugreek significantly differs economics in fenugreek. However, results of the present investigation indicated that the application of 60 kg P_2O_5 ha^{-1} secure the maximum net returns (Rs 43596/ha) and B:C ratio (2.66) which was significantly superior over all other treatments but remained at par with the application of 40 kg P_2O_5 ha^{-1} (Rs. 40867/ha) and B:C ratio (2.59). This might be due to higher yield obtained with same treatments during the present investigation.

Effect of foliar application of zinc on growth attributes

The foliar application of zinc proved better for all growth characters as compared to water spray treatments. Minimum growth characters were produced under water spray. However, results showed that the application of zinc as 0.5 % spray at 40 and 60 days stage recorded the maximum value of plant height (35.11 and 46.65 cm) and dry matter accumulation (0.393, 4.61 and 7.76 g $plant^{-1}$) Sammauria and Yadav (2008) [7] also 54 reported that increasing levels

of Zn increased the number of branches per plant in fenugreek. The increase in plant height, dry matter accumulation with foliar application of zinc may be ascribed due to sufficient availability of zinc to plant which might have enhanced catalytic or stimulatory

Table 1 Effect of phosphorus and zinc application on growth and yield attributes of fenugreek

Treatments	Plant height (cm)		Plant Dry matter (g Plant^{-1})		Yield attributes			
	60 DAS	At maturity	60 DAS	At harvest	No. of pods/plant	Pod length (cm)	Seeds/ pod	Test weight (g)
Basal application of Phosphorus								
P1 Control (0 kg ha^{-1})	29.15	38.85	1.48	4.48	19.15	8.82	9.15	10.16
P2 20 kg ha^{-1}	32.56	43.70	3.45	6.45	22.56	10.23	12.56	11.18
P3 40 kg ha^{-1}	34.87	45.90	4.68	7.68	24.87	11.57	14.42	11.87
P4 60 kg ha^{-1}	35.34	46.83	4.94	7.94	25.45	11.94	14.79	12.23
SEm+	0.29	0.37	0.18	0.21	0.24	0.24	0.34	0.25
CD (P = 0.05)	0.84	1.10	0.51	0.54	0.71	0.70	0.99	0.72
Foliar application of zinc								
F1 Water spray	29.83	39.53	2.58	5.58	19.91	9.24	9.91	10.67
F2 0.5 % spray at 40 days stage	34.00	45.29	3.89	6.89	24.00	10.87	13.67	11.55
F3 0.5 % spray at 40 and 60 days stage	35.11	46.65	4.61	7.76	25.11	11.80	14.61	11.86
SEm+	0.33	0.43	0.20	0.22	0.28	0.28	0.39	0.28
CD (P = 0.05)	0.98	1.26	0.59	0.61	0.82	0.81	1.14	0.83

Effect on most of the physiological and metabolic processes of plant. Important role in regulating the auxin concentrations in plants, independently of its effect on growth. Zinc also enhances the absorption of essential elements via increasing the cation exchange capacity of roots. Zinc sulphate treatment was found to increase the photosynthetic activity and the rate of respiration which results in improved the growth. Agarwal *et al*. (2008) [8] confirmed the similar finding that foliar spray of micronutrients (Zn, B, Fe and Cu) gives superior plant height, number of branches in fenugreek.

Effect of foliar application of zinc on yield attributes

The study on the effect of foliar spraying zinc on the yield attributes viz., number of pods, length of pod, seeds per pod and test weight of fenugreek presented in Table 1. There were notable variations in the statistical analysis of the different treatments of zinc as foliar application. Results revealed that the highest no. of pods per plant (25.11), pod length (11.80), no. of seeds per pod (14.61) and test weight (11.86 g) obtained with the application of zinc as 0.5 % foliar spray at 40 and 60 days stage. However, the added micronutrient, zinc was vital for various physiological processes such as cell division, elongation, and photosynthesis, which directly influence pod development. The synergistic effect of this comprehensive nutrient mix enhances the plant's metabolic functions, leading to better growth and elongation of pods. Adequate nutrient supply ensures that the plants can sustain prolonged growth phases, resulting in no. of pods, seeds per pods and longer pods. Compared to other treatment combinations. This comprehensive nutrient support allows the plants to maximize their genetic potential for the no. of pods, seeds per pods pod length, resulting in significantly higher no. of pods, seeds per pods and longer pods than those produced with other treatments. The outcomes 55 in the fenugreeks aligned with the findings of Muindi *et al*., (2020) [9], Kavya *et al*., (2021) [10], and Dhaliwal *et al*., (2023) [11]. Further, analysis of data indicated that the application of zinc as 0.5 % foliar spray at 40 and 60 days stage also recorded the highest seed yield (1366 kg ha^{-1}), straw yield (2375 kg ha^{-1}) and biological yield (3741 kg ha^{-1}). However, a complex optimization of plant growth and reproductive processes can be responsible for the higher yield of fenugreek. This may be due to application of zinc in a balanced manner at the designated concentration promotes improved metabolic activities that are essential for reproductive processes like pollination, flower initiation, and seed filling. By optimizing the plants' reproductive potential, this integrated approach to nutrient management increases the number of seeds produced by each plant. In contrast to the control group and other micronutrient treatments, this combination of treatments promotes better resource utilization, which leads to a higher quantity of seeds produced per individual plant, indicative of enhanced crop productivity and yield. The outcomes in the fenugreek aligned with the findings of Gidaganti *et al*. (2019) [12].

Effect of foliar application of zinc on economics

It can be inferred from the data that all the treatments of foliar application for zinc evaluated for their efficacy in fenugreek brought about significantly higher the net returns 56 than water spray (**Table 2**). The maximum net returns of Rs 42577/ha and B:C ratio (2.65) were achieved with the application of zinc as 0.5 % spray at 40 and 60 days stage. However, it showed statistical equivalence with the application of zinc as 0.5 % spray at 40 days stage. Higher benefit cost ratio was recorded with the application of zinc might be due to higher grain and strove yield which resulted in increases the gross return, ultimately increases the benefit ratio Gidaganti *et al*. (2019) [12].

Table 2 Effect of Phosphorus and zinc application on yields and economics of fenugreek

Treatments	Yields			Economics	
	Seed yield	Biological yield	Harvest index	Net returns (Rs. ha-1)	B:C ratio
Basal application of Phosphorus					
P1 Control (0 kg ha^{-1})	915	2830	31.87	21342	1.87
P2 20 kg ha^{-1}	1208	3415	35.26	35415	2.42
P3 40 kg ha^{-1}	1331	3662	36.22	40867	2.59
P4 60 kg ha^{-1}	1397	3805	36.59	43596	2.66
SEm+	25	52	0.23	1253	0.05
CD (P = 0.05)	73	152	0.69	3675	0.14
Foliar application of zinc					
F1 Water spray	991	2982	32.78	24745	1.99
F2 0.5 % spray at 40 days stage	1281	3561	35.77	38593	2.51
F3 0.5 % spray at 40 and 60 days stage	1366	3741	36.41	42577	2.65
SEm+	29	60	0.27	1447	0.06
CD (P = 0.05)	85	175	0.80	4243	0.17

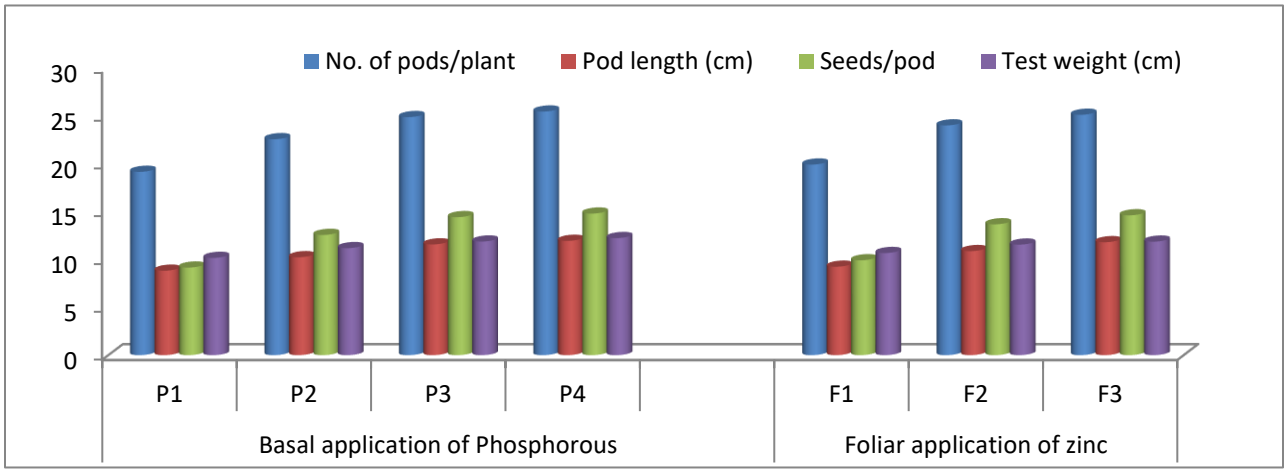

Figure 1 Effect of Phosphorus and zinc application on yield attributes of fenugreek

Conclusion

Application of 60 kg P_2O_5 ha^{-1} recorded higher net return (Rs. 43596 ha^{-1}) and B:C ratio (2.66) while it was found at par with application of 40 kg P_2O_5 ha^{-1} which recorded similarly net returns and B:C ratio. Therefore it is suggested to apply 40 kg P_2O_5 ha^{-1} optimum for fenugreek to obtain higher net return and benefit per rupee investment. The superior growth, development and yield parameters were recorded due to the application of zinc as foliar spray at 40 and 60 days stage. It was found superior in respect of net monetary returns (Rs. 42577 ha^{-1}) and higher B: C ratio (2.65). Hence it is recommended to apply higher quantity of nutrients to fenugreek crop as a recommended dose.

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Publication History

Received	02.05.2026
Revised	20.05.2026
Accepted	22.05.2026
Online	30.05.2026