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Modulation of Phytonutrient Profile, Antioxidant and Antibacterial Activity of Fenugreek Grown in Polluted Soil Using Chemical and Biofertilizers: A Review

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Abstract

Fenugreek (*Trigonella foenum-graecum* L.) is a well-known medicinal and nutritionally important leguminous plant widely used in traditional medicine and functional foods. Its seeds and leaves are rich sources of phytonutrients such as alkaloids, flavonoids, saponins, phenolic acids, vitamins, and minerals, which are responsible for its diverse pharmacological activities. Rapid urbanization and industrialization have led to increasing soil pollution, which can significantly influence plant metabolism, nutrient uptake, and secondary metabolite production. Simultaneously, the use of chemical fertilizers and biofertilizers such as vermicompost and municipal compost has been explored as a strategy to improve soil fertility and crop quality under stressed environments. The present review critically compiles and analyses available scientific literature on the phytonutrient profile, antioxidant, and antibacterial activities of fenugreek, with special emphasis on plants grown in polluted soils and treated with chemical fertilizers and biofertilizers (vermicompost and compost prepared by the Indore Municipal Corporation). The review also integrates findings from the author's previous experimental work to highlight how fertilizer treatments modulate bioactive compound accumulation and biological activities in fenugreek. The article concludes that biofertilizer application, particularly vermicompost, can mitigate the adverse effects of soil pollution and enhance the medicinal value of fenugreek, supporting its sustainable cultivation and therapeutic relevance.

Keywords: Fenugreek, phytonutrients, antioxidant activity, antibacterial activity, polluted soil, vermicompost, biofertilizer.

1. Introduction

Fenugreek (*Trigonella foenum-graecum* L.), belonging to the family Fabaceae, is an annual herb cultivated extensively in India, the Mediterranean region, and parts of Africa and Asia. It is valued both as a spice and as a medicinal plant in Ayurveda, Unani, and traditional folk medicine. Fenugreek seeds and leaves are traditionally used for the management of diabetes, inflammation, digestive disorders, microbial infections, and oxidative stress-related diseases.

In recent years, environmental pollution, particularly soil contamination with heavy metals and industrial wastes, has emerged as a serious concern affecting agricultural productivity and food quality. Polluted soils can alter plant growth, nutrient uptake, and secondary metabolite synthesis. Interestingly, stress

conditions such as soil pollution may also induce the production of certain secondary metabolites, thereby modifying the phytonutrient and antioxidant profile of medicinal plants.

Fertilizer management plays a crucial role in determining plant health and biochemical composition. While chemical fertilizers enhance crop yield, their excessive use can further deteriorate soil health. Biofertilizers such as vermicompost and compost prepared from municipal organic waste have gained importance due to their eco-friendly nature, nutrient richness, and ability to improve soil structure and microbial activity. The integration of chemical and biofertilizers is increasingly being studied as a sustainable approach to improve both yield and quality of medicinal plants under polluted soil conditions.

This review focuses on fenugreek as a model medicinal plant to understand how polluted soil and different fertilizer treatments influence its phytonutrient composition, antioxidant potential, and antibacterial activity.

2. Botanical Description and Agronomic Importance of Fenugreek

Trigonella foenum-graecum L. is an erect, annual herb reaching a height of 30–60 cm. The plant bears trifoliate leaves, small white to yellowish flowers, and elongated pods containing 10–20 hard, yellowish-brown seeds. Fenugreek is a nitrogen-fixing legume, contributing to soil fertility through symbiotic association with *Rhizobium* species.

Agronomically, fenugreek is a short-duration crop adaptable to diverse soil and climatic conditions. Its ability to grow in marginal and stress-prone soils makes it a suitable candidate for cultivation in polluted or degraded lands, provided appropriate soil management practices are adopted.

Scientific classification-

Kingdom	Plantae
Order	Fabales
Family	Fabaceae
Genus	Trigonella
Species	Trigonella foenum-graecum

Fenugreek Seeds **Fenugreek micro-green**

3. Phytonutrient Profile of Fenugreek

Fenugreek is a rich reservoir of bioactive compounds that contribute to its medicinal value.

3.1 Alkaloids

The most prominent alkaloid in fenugreek is trigonelline, which exhibits antidiabetic, neuroprotective,

and antimicrobial properties. Other alkaloids such as choline and gentianine have also been reported.

3.2 Flavonoids and Phenolic Compounds

Fenugreek contains flavonoids such as quercetin, kaempferol, vitexin, and isovitexin, along with phenolic acids like gallic acid, caffeic acid, and ferulic acid. These compounds play a major role in antioxidant and antimicrobial activities.

3.3 Saponins

Steroidal saponins, particularly diosgenin, are characteristic constituents of fenugreek seeds. Diosgenin is an important precursor for the synthesis of steroidal drugs and exhibits anti-inflammatory, antioxidant, and antibacterial activities.

3.4 Nutritional Components

Fenugreek seeds are rich in proteins, dietary fiber, essential amino acids, vitamins (A, C, and B-complex), and minerals such as iron, calcium, and zinc. The combined nutritional and medicinal properties make fenugreek a functional food.

4. Effect of Polluted Soil on Phytonutrient Accumulation

Soil pollution, particularly with heavy metals and industrial residues, can influence plant metabolism. Several studies have reported that plants grown in polluted soils exhibit altered levels of phenolics, flavonoids, and antioxidants. In fenugreek, moderate stress conditions may stimulate the biosynthesis of secondary metabolites as a defence mechanism, whereas severe contamination can inhibit growth and reduce overall biomass.

The author's previous experimental observations indicated that fenugreek grown in polluted soil showed variations in phytonutrient content, suggesting stress-induced modulation of secondary metabolite pathways. These findings support the concept that environmental stress can significantly affect the medicinal quality of plants.

5. Role of Chemical Fertilizers and Biofertilizers

5.1 Chemical Fertilizers

Chemical fertilizers provide readily available nutrients and enhance vegetative growth and yield. However, their long-term use may negatively affect soil microbial diversity and sustainability. In polluted soils, chemical fertilizers may increase nutrient availability but do not address soil health issues.

5.2 Vermicompost

Vermicompost is an organic fertilizer produced through the activity of earthworms. It is rich in macro- and micronutrients, plant growth regulators, and beneficial microorganisms. Studies have shown that vermicompost application enhances phenolic and flavonoid content, antioxidant activity, and microbial resistance in medicinal plants, including fenugreek.

5.3 Municipal Compost (Indore Municipal Corporation)

Compost prepared from segregated organic waste by the Indore Municipal Corporation represents a sustainable approach to waste management and soil fertility improvement. Such compost improves soil structure, water-holding capacity, and microbial activity. When applied to polluted soils, it can reduce metal bioavailability and improve plant biochemical parameters.

The author's work demonstrated that fenugreek treated with vermicompost and municipal compost exhibited improved phytonutrient content and biological activities compared to plants treated with chemical fertilizers alone.

6. Antioxidant Activity of Fenugreek

Oxidative stress is associated with numerous chronic diseases. Fenugreek extracts have shown strong antioxidant activity in various in vitro assays such as DPPH, ABTS, and FRAP, attributed mainly to phenolics, flavonoids, and saponins.

Plants grown under biofertilizer treatment, particularly vermicompost, generally exhibit enhanced antioxidant potential. This enhancement is linked to improved nutrient availability and stimulation of secondary metabolite synthesis. Fenugreek grown in polluted soil and treated with biofertilizers has been reported to show higher antioxidant activity than untreated controls, indicating the protective role of organic amendments.

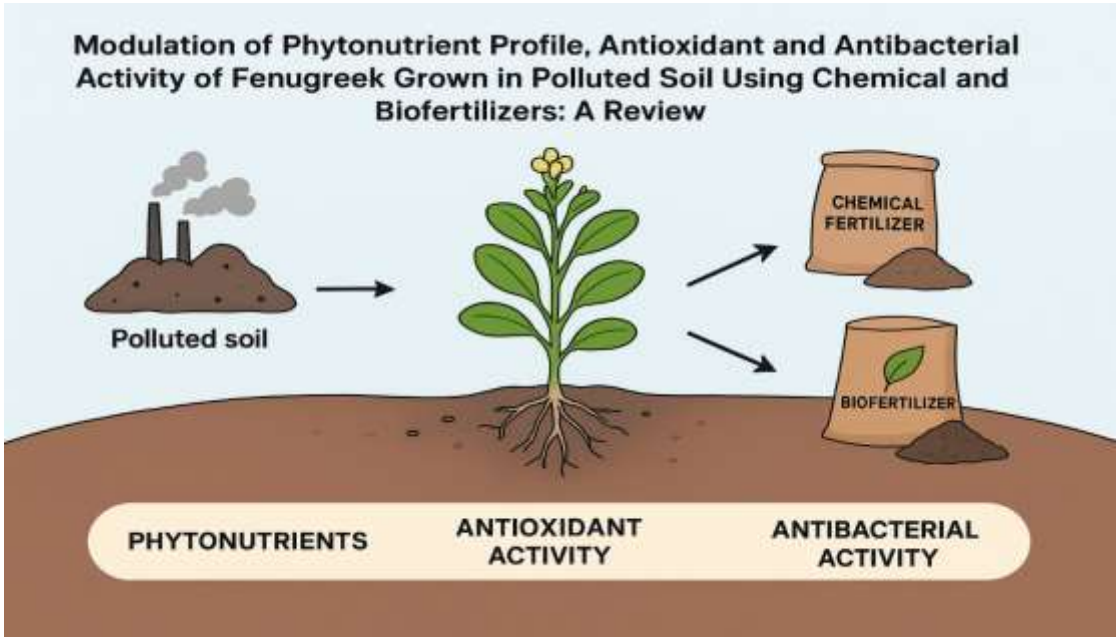
7. Antibacterial Activity of Fenugreek

Fenugreek extracts have demonstrated antibacterial activity against a range of Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, and *Pseudomonas aeruginosa*. The antibacterial effect is attributed to the presence of alkaloids, flavonoids, saponins, and phenolic compounds.

Experimental findings from the author's study indicated that fertilizer treatments significantly influenced the antibacterial efficacy of fenugreek extracts. Plants treated with vermicompost and municipal compost showed enhanced antibacterial activity, possibly due to increased accumulation of bioactive compounds.

8. Integration of Author's Previous Work with Existing Literature

The author's research on fenugreek grown in polluted soil and treated with chemical and biofertilizers aligns well with existing literature emphasizing the role of organic amendments in improving plant biochemical quality. The findings provide experimental support to the hypothesis that biofertilizers not only enhance growth but also improve antioxidant and antibacterial properties, even under adverse soil conditions.



9. Conclusion and Future Prospects

Fenugreek is a valuable medicinal plant with significant phytonutrient, antioxidant, and antibacterial potential. Soil pollution poses challenges to its cultivation; however, appropriate fertilizer management can mitigate negative effects. Biofertilizers such as vermicompost and municipal compost emerge as sustainable and effective alternatives to chemical fertilizers, enhancing both soil health and medicinal quality of fenugreek.

Future research should focus on molecular mechanisms underlying stress-induced secondary metabolite synthesis, long-term field studies in polluted environments, dose optimization of municipal composts, and metabolomics-based standardization of fenugreek grown under stressed and amended soils.

References:

1. Ahmad, P., Alyemeni, M. N., Wijaya, L., Alam, P., Ahanger, M. A., & Ashraf, M. (2019). Upregulation of antioxidant defense system in plants under environmental stress. Frontiers in Plant Science, 10, 1–13.
2. Chaudhary, S., Choudhary, A., Sharma, A., & Singh, R. (2021). Phytochemical profiling and antioxidant potential of Trigonella foenum-graecum under different agronomic practices. Journal of Applied Research on Medicinal and Aromatic Plants, 22, 100295.
3. Dixit, P., Ghaskadbi, S., Mohan, H., &Devasagayam, T. P. A. (2005). Antioxidant properties of germinated fenugreek seeds. Phytotherapy Research, 19(11), 977–983.
4. Kumar, M., Tomar, M., Punia, S., Grasso, S., Arrutia, F., Choudhary, J., & Singh, S. (2020). Fenugreek (Trigonella foenum-graecum L.) seeds: Nutritional composition, bioactive compounds, and health benefits. Food Chemistry, 315, 126239.
5. Pandey, V. C., Bajpai, O., Singh, N., & Singh, S. K. (2019). Soil pollution and remediation strategies for sustainable agriculture. Environmental Sustainability, 2(1), 1–14.
6. Saha, S., Mina, B. L., Gopinath, K. A., Kundu, S., & Gupta, H. S. (2010). Relative changes in soil properties as influenced by organic amendments. Bioresource Technology, 101(11), 4575–4581.
7. Sharma, S., & Singh, V. (2022). Effect of vermicompost on growth, phytochemicals and antioxidant activity of medicinal plants. Industrial Crops and Products, 176, 114306.
8. Yadav, G. S., Das, A., Lal, R., Babu, S., Meena, R. S., Saha, P., & Datta, M. (2017). Impact of organic farming on soil health and crop productivity. Agronomy Journal, 109(5), 1–12.