



Review Article

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Exploring genetic and morphological diversity of fenugreek (*Trigonella foenum-graecum* L.) in Uttarakhand: A Review

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ABSTRACT

Fenugreek (*Trigonella foenum-graecum* L.) is an important spice and medicinal herb that is widely cultivated in Uttarakhand, India. The state of Uttarakhand is known for its rich diversity of fenugreek, which provides a valuable source of genetic material for breeding programs to improve the crop's productivity, quality, and resilience. Fenugreek has a long history of use in the region, both as a food and as a medicine, and its diversity is an important part of the cultural heritage of the region. In this review, we provide an overview of the diversity of fenugreek in Uttarakhand, including its geographical distribution, genetic and morphological diversity, nutritional and medicinal properties, and traditional uses. We also discuss the threats to fenugreek diversity in the region and the importance of conserving it for food security, medicinal value, cultural heritage, and environmental sustainability. The review highlights the need for continued research and conservation efforts to ensure the preservation of fenugreek diversity in Uttarakhand.

Keywords: *Trigonella foenum-graecum* L., Genetic diversity, Morphological diversity, Nutritional properties, Medicinal properties.

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an herbaceous plant that belongs to the family Fabaceae^[1]. It is a popular spice and medicinal herb that is widely cultivated in many parts of the world, including India, Egypt, and Morocco^[2]. Fenugreek has a bitter taste and a strong aroma, and its seeds and leaves are used for various culinary and medicinal purposes. The seeds of fenugreek are commonly used in Indian, Middle Eastern, and North African cuisines to flavor dishes and as a key ingredient in spice blends such as curry powder^[3]. In addition, fenugreek is used in traditional medicine to treat a range of health conditions, including diabetes, digestive problems, and respiratory ailments. Fenugreek is an important spice and medicinal herb due to its unique flavor and medicinal properties. In terms of its culinary uses, fenugreek seeds are commonly used to flavor curries, stews, and other dishes in many cuisines around the world. It is a popular ingredient in Indian, Middle Eastern, and North African dishes, adding a distinct aroma and flavor to these foods. In terms of its medicinal properties, fenugreek has been used for centuries in traditional medicine to treat a variety of health conditions. It is believed to have anti-inflammatory, antioxidant, and anti-diabetic properties, among others. Fenugreek has been shown to help regulate blood sugar levels, lower cholesterol levels, improve digestive health, and support lactation in nursing mothers^[4]. The medicinal properties of fenugreek are due to its active compounds, which include saponins, flavonoids, and alkaloids. These compounds are known to have a range of beneficial effects on the body, including reducing inflammation and fighting oxidative stress. Overall, the importance of fenugreek as a spice and medicinal herb cannot be overstated. Its unique flavor and health benefits make it a valuable ingredient in many cuisines and a popular herbal remedy for various health conditions.

Uttarakhand is an important source of fenugreek diversity due to its unique agroclimatic conditions, which provide a suitable environment for the growth of this herb. The state is in the northern part of India and is known for its diverse topography, ranging from the Himalayan mountains in the north to the Terai plains in the south. This diverse landscape creates a range of microclimates that are ideal for the cultivation of different crops, including fenugreek. Uttarakhand is home to a rich diversity of fenugreek varieties, which have adapted to the local environmental conditions over time. These varieties differ in terms of their morphological characteristics, such as seed size, color, and shape, as well as their nutritional and medicinal properties. This diversity is important for farmers, who can choose from a range of varieties that

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are best suited to their specific growing conditions and market demands. In addition to its diversity of fenugreek varieties, Uttarakhand is also an important center for the cultivation and processing of fenugreek. The state is known for producing high-quality fenugreek seeds, which are in demand both domestically and internationally. Fenugreek is an important crop for farmers in Uttarakhand, providing them with a source of income and livelihood. Overall, the importance of Uttarakhand as a source of fenugreek diversity cannot be overstated. The state's unique agroclimatic conditions have created a diverse range of fenugreek varieties, which are important for farmers and consumers alike.

Historical and cultural significance:

Fenugreek has been used for various purposes in Uttarakhand for centuries. In the traditional systems of medicine, such as Ayurveda and Unani, fenugreek is highly valued for its medicinal properties^[5]. The herb has been used to treat a variety of health conditions, including digestive disorders, respiratory ailments, and skin problems. In addition to its medicinal uses, fenugreek is also an important ingredient in local cuisine. In Uttarakhand, fenugreek leaves and seeds are used to flavor various dishes, such as dal (lentil soup), sabzi (vegetable stir-fry), and roti (flatbread)^[6]. The herb adds a distinct flavor and aroma to these dishes, which are enjoyed by locals and visitors alike. Fenugreek is also used for non-culinary purposes in Uttarakhand. The herb is used to make cosmetics, such as face masks and hair oil, which are believed to have a range of skin and hair benefits. Fenugreek is also used in livestock feed to improve milk production and overall health of the animals. Overall, fenugreek has played an important role in the culture and history of Uttarakhand^[7]. Its medicinal and culinary uses have been passed down through generations, and it continues to be an important crop for farmers in the region. Fenugreek has been used for various medicinal purposes in Uttarakhand for centuries.

Therapeutic uses:

Fenugreek (*Trigonella foenum-graecum* L.), an herb deeply rooted in the traditional medicine practices of Uttarakhand, holds immense potential for various medicinal applications^[7]. This versatile herb has been utilized for generations to address a wide range of health concerns in the region. One of the noteworthy traditional uses of fenugreek in Uttarakhand lies in its ability to promote digestive health^[8]. Consumption of fenugreek seeds has been associated with improved digestion, relief from indigestion, and alleviation of discomfort related to bloating and stomach issues. The carminative properties of fenugreek are highly regarded for their effectiveness in reducing gas and enhancing overall digestive function^[9]. In addition, fenugreek has a long-standing tradition of use in alleviating joint and muscle pain. Both topical application and internal consumption of fenugreek seeds have been attributed with anti-inflammatory properties, offering relief from conditions such as arthritis and muscle strains. The significance of fenugreek in women's health cannot be understated. It is believed to possess estrogen-like properties that contribute to the regulation of menstrual cycles, alleviation of menstrual cramps, and mitigation of menopausal symptoms. Moreover, fenugreek is commonly employed to support lactation in nursing mothers, stimulating milk production and enhancing breastfeeding^[10]. Respiratory ailments find effective remedies in fenugreek within Uttarakhand's traditional medicine practices. The seeds are employed to address conditions such as cough, bronchitis,

and congestion due to their expectorant properties. Fenugreek is reputed for its ability to loosen and expel mucus from the respiratory tract, thereby promoting easier breathing. Furthermore, fenugreek is a valuable component of traditional skincare remedies in Uttarakhand. Its antimicrobial properties have been utilized to treat skin issues like acne, eczema, and infections. Topical application of fenugreek paste or oil is believed to possess anti-inflammatory effects, combat microbial infections, and facilitate skin healing. While fenugreek's traditional uses in Uttarakhand are rooted in historical knowledge and practices, further research is necessary to substantiate its efficacy and explore its active compounds. Given the potential of fenugreek as a natural remedy, collaboration between traditional medicine practitioners and modern scientific researchers can pave the way for evidence-based insights and new avenues of therapeutic applications.

Culinary uses

Fenugreek is an important ingredient in the cuisine of Uttarakhand. The herb is used in various forms, including fresh leaves, dried leaves, and seeds, to add flavor and aroma to dishes. Fenugreek leaves are commonly used to flavor dal, a lentil soup that is a staple in Uttarakhand^[11]. The leaves are added to the soup along with other spices and herbs, giving it a distinct flavor and aroma. Fenugreek leaves and seeds are also used to flavor vegetable stir-fries, known as sabzi in Uttarakhand. The leaves are usually chopped and added to the dish towards the end of the cooking process, while the seeds are often used as a spice in the tempering of the dish. Fenugreek leaves are sometimes added to the dough for making roti, a flatbread that is a common accompaniment to meals in Uttarakhand^[12]. The leaves are finely chopped and mixed with the flour and other ingredients, giving the roti a distinct flavor and aroma. Fenugreek seeds are sometimes used to make chutney, a condiment that is served with various dishes in Uttarakhand. The seeds are usually roasted and ground into a fine powder, which is then mixed with other ingredients such as garlic, ginger, and lemon juice to make a flavourful chutney^[13].

Geographical distribution of fenugreek in Uttarakhand

Fenugreek cultivation in Uttarakhand encompasses a wide range of regions, from the lower foothills to the high-altitude areas. The herb has adapted well to the diverse climatic and soil conditions found in the state, making it a profitable cash crop for many farmers^[6]. Understanding the major regions where fenugreek is grown in Uttarakhand provides valuable insights into the distribution and significance of its cultivation. The Terai region, which shares its border with the neighboring state of Uttar Pradesh, stands out as one of the primary areas for fenugreek cultivation in Uttarakhand^[14]. This region benefits from a warm and humid climate, creating favorable conditions for the herb to thrive. Another significant fenugreek-growing region is the Bhabar, situated at the foothills of the Himalayas^[14,15]. The Bhabar region is characterized by its sandy soil, which provides ideal conditions for fenugreek cultivation. Farmers in this area have capitalized on these natural attributes to cultivate fenugreek successfully. Moving further up, the lower Himalayan regions of Uttarakhand, including Dehradun and Haridwar, contribute significantly to fenugreek production. These areas offer a temperate climate, characterized by mild summers and cold winters, which proves favorable for fenugreek growth. The herb

finds a suitable environment in these regions, enabling farmers to cultivate it effectively. Even in the upper Himalayan regions of Uttarakhand, such as Uttarkashi and Chamoli, fenugreek cultivation is prevalent. However, the unique geographical features of these high-altitude areas present distinct challenges. Farmers here employ traditional farming practices, cultivating fenugreek in terraced fields. This demonstrates their deep-rooted knowledge and sustainable farming techniques passed down through generations. The distribution of fenugreek cultivation across these diverse regions of Uttarakhand highlights the adaptability of the herb to different environmental conditions. Understanding the significance of each region in fenugreek production contributes to the comprehensive documentation of its cultivation practices. Moreover, this knowledge serves as a foundation for promoting sustainable farming, preserving traditional agricultural practices, and ensuring the continued success of fenugreek cultivation in Uttarakhand.

Genetic and morphological diversity of fenugreek in Uttarakhand

Uttarakhand, a region renowned for its fenugreek cultivation, showcases significant genetic diversity not only within the widely cultivated *Trigonella foenum-graecum* L. species but also within the broader *Trigonella* genus. While *Trigonella foenum-graecum* L. remains the primary species cultivated in the region, there is potential for the presence of other fenugreek species, each with its distinct characteristics and attributes^[16]. One such species is *Trigonella suavissima*, commonly known as sweet fenugreek or Arabian fenugreek, which typically thrives in the Middle East and North Africa. Although its occurrence in Uttarakhand necessitates further investigation, it is plausible that related varieties or subspecies may be found within the region's fenugreek population. *Trigonella monantha*, referred to as single-flowered fenugreek, is native to the Mediterranean region. It features solitary yellow flowers, and it is conceivable that variations or related forms of this species exist in Uttarakhand's fenugreek diversity. *Trigonella coerulescens*, known as blue-flowered fenugreek, can be found in parts of Asia and Europe^[14]. While its distribution in Uttarakhand may be limited, it is conceivable that specific local varieties or related species may be present, contributing to the overall fenugreek genetic diversity. Another species, *Trigonella corniculata*, commonly known as slender-leaf fenugreek or horned clover, is widespread in various parts of Asia, including India. Its slender leaves and small yellow flowers distinguish it, and it is reasonable to assume that this species or related varieties may be present in Uttarakhand. *Trigonella polycerata*, also known as many-horned fenugreek, is native to the Himalayan region. This species is characterized by its distinct multiple horn-like projections on the fruits. Given the proximity of Uttarakhand to the Himalayas, it is likely that certain regions of the state harbor this species, contributing to the genetic diversity of fenugreek in the area. Additionally, *Trigonella caerulea*, known as blue fenugreek, is native to Central and Eastern Europe. While further investigation is required to confirm its presence in Uttarakhand, it is plausible that this species or related forms could be cultivated in specific regions of the state. *Trigonella stellata*, commonly referred to as star fenugreek, is found in parts of North Africa and the Middle East. It is conceivable that related varieties or species within the *Trigonella stellata* complex may also exist in Uttarakhand, contributing to the overall diversity of fenugreek species in the region.

To obtain a comprehensive understanding of the genetic diversity and distribution of fenugreek species in Uttarakhand, in-depth botanical surveys and molecular studies are essential. These studies can provide valuable insights into the unique genetic traits, adaptations, and potential applications of different fenugreek species. Collaboration among researchers, botanists, and local communities is crucial for the systematic documentation, conservation, and sustainable utilization of fenugreek genetic resources in Uttarakhand. This comprehensive knowledge will not only contribute to the region's agricultural practices but also enhance medicinal, culinary, and industrial applications associated with fenugreek. By leveraging its diverse fenugreek resources, Uttarakhand can promote sustainable development and make significant contributions to the broader scientific understanding of this valuable plant species.

Nutritional composition

Fenugreek seeds (*Trigonella foenum-graecum* L.) cultivated in Uttarakhand exhibit a remarkable nutritional profile, characterized by substantial levels of essential nutrients and bioactive compounds. A comprehensive study conducted in the Kumaon region of Uttarakhand unveiled the nutrient and compound percentages in fenugreek seeds, showcasing protein content ranging from 25.7% to 28.2% and dietary fiber ranging from 23.5% to 25.9%. Furthermore, these seeds serve as a rich source of vital vitamins, including thiamine, riboflavin, niacin, and vitamin C, along with an array of minerals such as iron, magnesium, calcium, and phosphorus. Additionally, fenugreek seeds contain an array of bioactive compounds, including saponins, alkaloids, flavonoids, and phenolic compounds, which contribute to their notable medicinal properties. This substantial nutritional composition highlights the immense potential of Uttarakhand-grown fenugreek seeds as a valuable dietary supplement and functional food ingredient.

Threats to fenugreek diversity

Despite the importance of fenugreek in Uttarakhand, there are several threats to its diversity and sustainability. The natural habitats of fenugreek in Uttarakhand are being destroyed due to human activities such as deforestation, urbanization, and agriculture. As a result, the natural populations of fenugreek are declining rapidly. Climate change is affecting the growth and distribution of fenugreek in Uttarakhand^[17]. Changes in temperature and rainfall patterns are affecting the phenology, growth, and yield of fenugreek. The traditional farming practices in Uttarakhand, such as seed saving and exchange, are disappearing due to modernization and commercialization of agriculture. This has resulted in the loss of local landraces and the homogenization of the fenugreek gene pool. Fenugreek is susceptible to various pests and diseases, which can significantly reduce its yield and quality. In Uttarakhand, fenugreek is attacked by pests such as aphids, whiteflies, and pod borers, and diseases such as powdery mildew and root rot. There is a lack of awareness and conservation efforts for fenugreek diversity in Uttarakhand. The local communities, farmers, and policymakers need to be aware of the importance of fenugreek diversity and the need for its conservation.

Importance of conserving fenugreek diversity

Conserving fenugreek diversity in Uttarakhand holds significant importance across multiple aspects. Firstly, it contributes to food

security by safeguarding a wide range of genetic resources that can be utilized in breeding programs to enhance fenugreek's productivity, quality, and resilience to pests and diseases^[18]. By preserving fenugreek diversity, a stable and diverse food supply can be ensured for local communities, promoting food security. Secondly, fenugreek possesses valuable medicinal properties, and its diversity harbors a rich reservoir of compounds with potential medicinal applications^[19]. Conserving fenugreek diversity becomes crucial to safeguard these valuable medicinal properties for future generations, ensuring the availability of diverse sources for medicinal purposes. Furthermore, fenugreek is deeply intertwined with the cultural heritage of Uttarakhand. The diverse varieties of fenugreek and the associated knowledge and practices are integral to the local culture and traditions. Conservation efforts aimed at fenugreek diversity can preserve this cultural heritage, maintaining the vital connection between local communities and their agricultural traditions^[20]. In addition to its cultural significance, fenugreek contributes to environmental sustainability. As a sustainable crop, fenugreek aids in soil and water conservation. Preserving fenugreek diversity enables the utilization of genetic resources to develop resilient varieties that are more tolerant to drought, pests, and diseases. This, in turn, promotes sustainable agricultural practices and fosters environmental sustainability.

Conserving fenugreek diversity in Uttarakhand is essential for food security, the preservation of valuable medicinal properties, the protection of cultural heritage, and the promotion of environmental sustainability. These conservation efforts not only benefit the local communities but also contribute to the overall well-being of the region and the sustainable development of agriculture.

CONCLUSION

Fenugreek diversity in Uttarakhand is important to conserve for several reasons. It is an important food crop and the diversity provides genetic material for breeding programs to improve productivity, quality, and resilience. Fenugreek also has numerous medicinal properties, and the diversity provides a rich source of compounds for medicinal use. It is an integral part of the local culture and traditions, and its diversity is an important part of the cultural heritage of the region. Fenugreek is a sustainable crop that can contribute to the conservation of soil and water resources. Conserving fenugreek diversity can ensure food security, promote medicinal value, preserve cultural heritage, and promote environmental sustainability.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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