

Green-seeded fenugreek: A new-found treasure for sustainable farming and income generation

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Fenugreek (methi) has long been a staple in Indian kitchens and traditional medicine. While yellow-seeded fenugreek (YSF) is commonly used, recent research at ICAR-NRCSS, Ajmer highlights green-seeded fenugreek (GSF) as a superior, climate-resilient alternative. Grown under Rajasthan's semi-arid conditions, GSF shows early, uniform germination and an extended vegetative phase, making it more tolerant to terminal heat stress common in semi-arid rabi conditions. Though slightly shorter than YSF, GSF consistently delivers higher seed and biomass yields, with heavier seeds especially under rainfed or limited irrigation making it ideal for marginal, low-input farming systems. Agronomically, its efficient root-to-shoot ratio supports better adaptability. GSF offers immense potential in functional foods, nutraceuticals, and export markets. With its agronomic and biochemical advantages, GSF stands ready to elevate fenugreek from a traditional spice to a climate-smart, health-forward crop for India's future.

Keywords: Chlorophyll, Climate resilient, Nutrition value, Semi-arid regions

FENUGREEK (*Trigonella foenum-graecum* L.) locally known as 'methi' is a time-honoured legume cultivated across India for its leaves and seeds. Traditionally used as a spice, condiment, and home remedy for various ailments, fenugreek has been part of Indian kitchens and folk medicine for centuries. However, the fenugreek we have grown and consumed for decades has largely been of the yellow-seeded type (YSF).

In recent years, green-seeded fenugreek (GSF) has emerged as a potential game-changer in both agriculture and health. Scientists at the ICAR-National Research Centre on Seed Spices (ICAR-NRCSS), Ajmer, have systematically studied and compared green and yellow-seeded genotypes during *rabi* seasons from 2021 to 2024. The results were highly encouraging and highlighted the potential significance of green-seeded fenugreek in climate-resilient agriculture, nutrition security, and functional food development. This article brings the key findings of

this multi-year research into the public domain, highlighting how GSF can redefine fenugreek's role from a simple spice crop to a vital nutraceutical and climate-smart resource.

Agro-climatic conditions

The trials were conducted under semi-arid agro-climatic conditions. Fifteen fenugreek genotypes comprising ten stable green-seeded germplasm lines (GSF 1, GSF 2, GSF 3, AFgGS-12, GSF 5, GSF 6, GSF 7, AFgGS-11, GSF 9 and GSF 10) registered with ICAR-National Bureau of Plant Genetic Resources and five released yellow-seeded check varieties (AFg-1 to AFg-5) were evaluated in a randomised block design (RBD) with three replications, using a plot size of 3 m × 3 m and spacing of 30 cm × 10 cm.

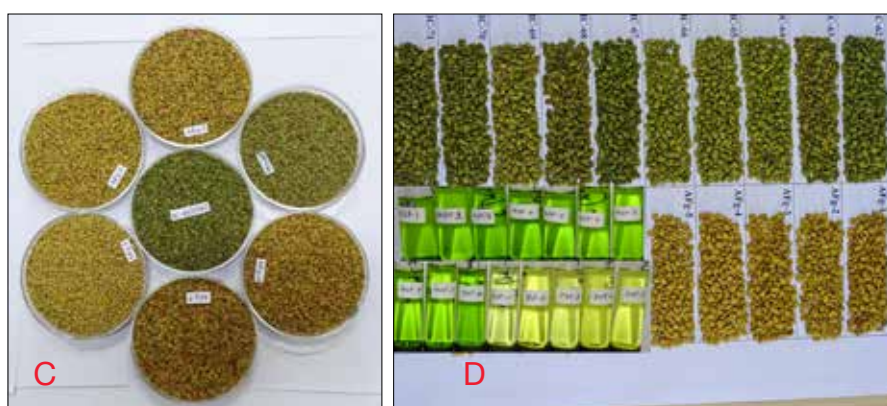
Germination, medicinal traits agro-morphological, and yield, were recorded following standard procedures, and the data were subjected to analysis of variance (ANOVA), appropriate for RBD

to determine the significance of genotypic differences across years.

Agronomic performance

Plant architecture and growth: Although YSF plants were taller at 75–81 cm and generally preferred for feed and fodder, GSF plants, despite being slightly shorter (62–71 cm), exhibited a superior harvest index, reflecting a more efficient conversion of total biomass into economic yield (seeds). GSF genotypes flowered and matured 3–4 days later than YSF, thereby enjoying an extended vegetative phase. This attribute can be advantageous under terminal heat stress, a common condition in *rabi* crops of northern India where prolonged vegetative growth helps plants accumulate more resources before setting seed.

Yield attributes: Despite being shorter in stature, GSF genotypes surpassed YSF in seed yield, biological yield, and thousand-seed weight. This was particularly evident under limited irrigation and rainfed conditions, suggesting that



(A) Field view of the GSF and YSF, (B) Plant morphology comparison for the GSF and YSF, (C) Seed colour comparison of the GSF and YSF, (D) Seed and extract for chlorophyll content for the GSF and YSF

higher diosgenin levels than YSF. This is significant because diosgenin is used as a raw material in the synthesis of various steroidal drugs.

Nutritional value

Phenolic compounds and antioxidant potential: GSF seeds had higher levels of total phenolic compounds that contribute to antioxidant activity, cellular repair, and chronic disease prevention. These phytochemicals protect the body from oxidative stress and have anti-inflammatory properties.

Chlorophyll and free amino acids: The deep green colour of GSF is not just cosmetic; it reflects higher chlorophyll content in seed, which is associated with photosynthetic efficiency, plant vigour, and potential health benefits. Additionally, free amino acid content was higher in GSF, enhancing its nutritional value for both human and animal consumption.

Sugar and oligosaccharide content: GSF seeds had significantly lower levels of simple sugars and oligosaccharides, making them suitable for diabetics and calorie-conscious consumers. Lower sugar content also improves digestibility and palatability, especially in dietary supplements.

GSF is better suited for low-input farming systems.

- Pods/plant and seeds/pod were statistically similar across both groups, but the bolder and heavier seeds of GSF contributed significantly to higher overall productivity.
- GSF also showed a better root-to-shoot ratio, indicating efficient resource allocation, a critical feature for crops grown in resource-limited environments.

Biochemical superiority: Nutraceuticals in every seed

Beyond agronomics, what truly sets GSF apart is its biochemical richness, particularly in compounds known to benefit human health. Biochemical analyses of 4-hydroxyisoleucine and diosgenin were carried out using standard ethanol-based extraction and

colourimetric estimation methods.

4-Hydroxyisoleucine (4-OHILE):

One of the most important discoveries in this study was the nearly two-fold increase in 4-hydroxyisoleucine (4-OHILE) content in GSF compared to YSF. This amino acid plays a crucial role in regulating insulin secretion and glucose metabolism, making it highly relevant for people managing diabetes and metabolic disorders. Top-performing genotypes like GSF 6, GSF 7, and GSF 10 recorded maximum levels of 4-OHILE, indicating their strong candidacy for functional food and pharmaceutical industries.

Diosgenin content: Diosgenin, a naturally occurring steroidal saponin, is known for its role in cholesterol control, hormonal therapy, and lipid metabolism. GSF genotypes showed moderately

Sustainability and climate resilience

Green seeded fenugreek genotypes exhibited excellent adaptability to water-limited conditions, a critical trait under the looming threat of climate change. Their early establishment, prolonged vegetative phase, and efficient nutrient use make them ideal candidates for:

- Rainfed agriculture
- Low-input organic systems
- Marginal lands with erratic rainfall

Furthermore, the lower requirement for fertilisers and pesticides in these genotypes supports sustainable and eco-friendly farming practices.

Scope for diversification and commercialisation

GSF holds remarkable promise for changing Indian agriculture

Table 1. Comparative agronomic performance and biochemical composition of green- and yellow-seeded fenugreek genotypes evaluated under semi-arid conditions of Rajasthan (Mean data of three years)

Genotype	Variety name	Plant height (cm)	No. of primary branches/plant	No. of seeds/pod	Seed yield (kg/ha)	4-OHlle (%)	Diosgenin (mg/100 g)	Chlorophyll (mg/100 g seed)	Total phenol (mg/100 g)	FAA (mg/100 g)
GSF (Green-seeded fenugreek)	GSF 1	62.0	4.9	17.9	1,848	0.81	382.3	0.678	21.22	1016.79
	GSF 2	68.5	5.2	17.5	1,941	0.75	412.6	0.495	41.55	931.02
	GSF 3	65.2	5.3	17.7	2,113	0.84	338.9	0.485	42.59	1048.95
	AFgGS-12	65.0	5.0	18.0	2,151	0.70	326.8	0.562	26.37	861.57
	GSF 5	63.2	5.4	17.6	1,815	0.75	366.7	0.480	31.36	937.04
	GSF 6	71.1	5.3	18.1	1,734	0.90	295.1	0.458	55.94	1124.76
	GSF 7	68.6	5.3	17.4	1,806	0.88	370.5	0.560	35.12	1094.87
	AFgGS-11	65.7	5.0	17.8	2,260	0.77	413.1	0.503	21.58	962.24
	GSF 9	69.8	4.9	18.4	1,817	0.81	388.4	0.455	38.98	1016.73
	GSF 10	68.7	5.1	18.1	1,806	0.85	261.8	0.482	18.17	1057.14
	Mean	66.8	5.1	17.9	1929.1	0.8	355.6	0.516	33.3	1005.1
YSF (Yellow-seeded fenugreek)	AFg-1	73.7	5.3	18.0	2,100	0.44	261.4	0.065	113.33	554.02
	AFg-2	80.9	5.3	17.9	2,027	0.48	508.1	0.043	116.21	606.39
	AFg-3	80.8	5.4	18.2	1,683	0.58	289.9	0.057	116.31	722.1
	AFg-4	79.5	5.2	18.3	2,120	0.73	319.6	0.075	96.78	911.99
	AFg-5	76.7	5.1	18.5	2,108	0.50	452.7	0.045	8.84	633.49
		Mean	78.3	5.3	18.2	2007.6	0.5	366.3	0.057	90.3
	CD (0.05%)	1.75	0.13	0.38	48.20	0.03	15.9	0.123	2.00	3.58

through crop diversification, value addition, and global market integration. Its unique combination of agronomic resilience and nutraceutical richness opens several pathways for commercialisation and income generation for farmers, entrepreneurs, and allied industries.

Herbal teas and infusions: Green methi seeds can be blended with other medicinal herbs to create teas that aid in digestion, regulate blood sugar, and support overall wellness.

Diabetic supplements: The high

4-hydroxyisoleucine content makes GSF an effective natural agent in managing blood sugar levels, enabling its inclusion in capsules, tablets, or powders targeting diabetic populations.

Nutritional powders and protein blends: GSF can be used to produce plant-based protein and nutritional powders that are suitable for fitness enthusiasts, elderly nutrition, and health-conscious individuals.

Fortified health drinks: As a source of natural amino acids, chlorophyll, and antioxidants, GSF

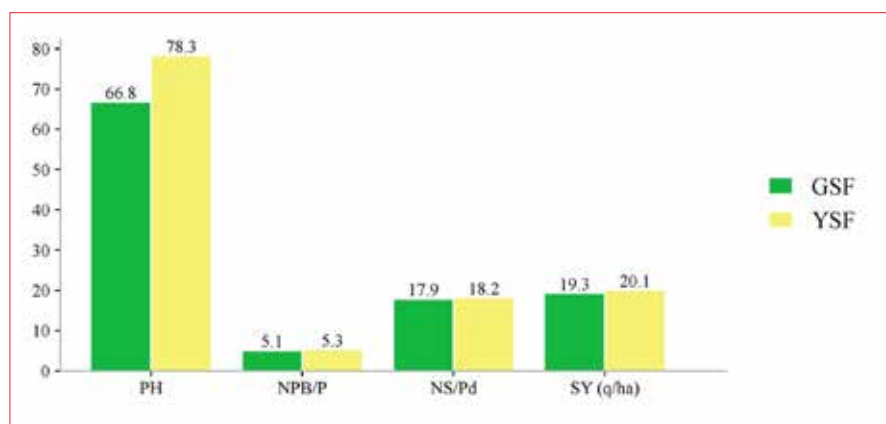
extracts can enhance the nutritional profile of health beverages, smoothies, and meal replacements.

Ayurveda and herbal medicine: GSF offers an effective plant-based remedy for metabolic, digestive, and hormonal disorders. 4-hydroxyisoleucine enhances insulin secretion, making it a natural therapeutic agent for Type 2 diabetes. Diosgenin, a precursor of steroidal hormones, can support hormonal balance in women, especially for menopausal symptoms and reproductive health. The seed's fibre and phytochemical content aid digestion and improve gut health, aligning well with ayurvedic detox and digestion-enhancing therapies.

These properties make GSF a candidate for inclusion in *churnas* (powders), *kwaths* (decoctions), *asavas* (fermented liquids), parathas, methi laddoo, sprouts, salad, and even modern herbal capsules.

Export potential

The global nutraceutical and herbal product markets are expanding rapidly, with increasing consumer preference for natural, plant-based, and functional ingredients. GSF offers a unique



Comparative agronomic traits of green-seeded (GSF) and yellow-seeded fenugreek (YSF) genotypes under semi-arid conditions

PH, plant height; NPBP, No. of primary branches/plant; NS/Pd, No. of seeds/pod; SY, Seed yield.

value proposition to tap into these markets due to its:

Distinct seed colour and appearance: The vibrant green colour appeals to premium health-conscious segments and signals freshness and uniqueness in international product lines.

High bioactive content: Scientific validation of compounds like 4-OHlle and diosgenin enhances consumer trust and marketability.

Versatility in applications: From supplements and teas to bakery products and dairy alternatives, GSF fits a broad spectrum of food and wellness products.

Export opportunities for GSF-based products are particularly strong in regions like Europe, North America, Australia, and Southeast Asia, where demand

for organic, vegan, gluten-free, and functional foods is steadily growing. Additionally, GSF can be promoted through GI tagging, organic certification, and traceable supply chains, enhancing its global competitiveness.

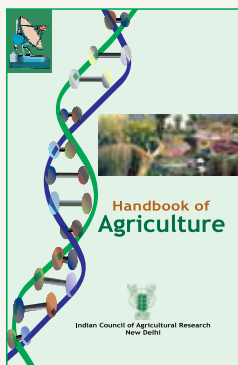
SUMMARY

Fenugreek has traditionally been cultivated as a yellow-seeded crop; however, green-seeded fenugreek (GSF) has emerged as a promising alternative. Studies at ICAR-NRCSS demonstrated its superior agronomic and biochemical traits under semi-arid conditions. GSF plants showed stable germination, better yield under limited-input conditions, and higher levels of nutraceutical compounds

including 4-hydroxyisoleucine, diosgenin, phenolics, chlorophyll, and amino acids. Nutritionally, GSF outshines YSF with nearly double the 4-hydroxyisoleucine (beneficial for diabetes) and higher diosgenin (linked to cholesterol control). The rich green seed coat (high chlorophyll), a visual marker of these benefits, also aids future breeding. The distinct green seed colour was also associated with enhanced chlorophyll and antioxidant content. The potential of GSF makes it a good option for nutraceutical use, sustainable agriculture, and value-added fenugreek products.

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