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Effect of growing media and seed density on growth, yield and quality of fenugreek (*Trigonella foenum-graecum*) microgreens

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Fenugreek (*Trigonella foenum-graecum* L.) is an important annual legume, valued for its nutritional and medicinal properties (Petropoulos 2017). Its adaptability to diverse agro-climatic conditions and nitrogen-fixing ability make it a key component of sustainable production systems. In recent years, microgreens have emerged as nutrient-dense functional foods rich in vitamins, minerals and bioactive compounds, offering significant potential for nutritional security and urban agriculture (Kyriacou *et al.* 2020, Khan *et al.* 2024a, Khan *et al.* 2025c). Despite growing interest, research on fenugreek microgreens remains limited, particularly with respect to optimising cultivation practices. Growing medium plays a critical role in microgreen production by influencing moisture retention, aeration, nutrient availability and root development. Soilless substrates such as cocopeat and other organic media have been reported to enhance germination, growth and phytochemical attributes due to their favourable physical and chemical properties (Di Gioia *et al.* 2017, Pathania *et al.* 2022, Paglialunga *et al.* 2023, Khan *et al.* 2025b). Seed density is another important factor affecting biomass production and canopy development; however, excessive density may lead to intra-specific competition, reducing individual plant growth and overall performance (Khan *et al.* 2025a).

In addition to growth and yield, quality parameters such as nitrate content are crucial for consumer safety, as their accumulation is influenced by substrate characteristics and crop management practices (Paglialunga *et al.* 2023, Khan *et al.* 2024b). However, limited information is available on the combined effects of growing media and seed density on growth, yield and quality traits of fenugreek microgreens. Therefore, the present study was undertaken to evaluate these factors to identify suitable production practices for efficient and safe microgreen cultivation.

The experiment was conducted during 2022–23 at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKAUST-K), Shalimar, Srinagar (34.14°N, 74.87°E), Jammu and Kashmir under controlled conditions (24 ± 2°C, 70 ± 5% RH, 12 h photoperiod, 10,000 lux). Uniform seeds of fenugreek were procured from the Division of Vegetable Science, SKAUST-K, Jammu and Kashmir. Seeds were surface sterilised with 1% sodium hypochlorite (1 min) and rinsed with distilled water (ISTA 2018). This treatment was applied for experimental purposes only and is not generally recommended for routine microgreen production. Five growing media, viz. soil (M_1), blotting paper (M_2), cocopeat (M_3), sawdust (M_4) and soil + vermicompost (1:1, v/v) (M_5) were evaluated. All media were sterilised prior to use, with soil, sawdust and blotting paper autoclaved at 121°C (15 psi) for 20–30 min, while cocopeat was treated with hot water (90–100°C) for 30 min. Medium properties, including bulk density and particle density (Black 1965), as well as total pore space and water-holding capacity (Piper 1966) were determined before sowing. The experiment was laid out in a factorial completely randomised design (F-CRD) with three seed densities [20 g (D_1), 25 g (D_2) and 30 g (D_3) 10 inch × 20 inch (12 cm × 90 cm) tray] and five media, resulting in 15 treatment combinations, each replicated three times.

Seeds were uniformly broadcasted over the growing media, evenly spread in trays and maintained under adequate moisture conditions. Microgreens were harvested at the first true leaf stage i.e. 10–12 days after sowing (DAS). Observations included germination percentage (ISTA 2018), seedling vigour index (SVI = germination % × seedling

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Table 1 Physico-chemical properties of growing media used in the study

Growing medium	Bulk density (kg/m³)	Total pore space (%)	Particle density (kg/m³)	Water-holding capacity (%)
M_1	1,435.5	38.8	1,120.9	60.5
M_2	800.8	78.6	734.9	310.7
M_3	409.97	67.6	550.7	530.2
M_4	180.5	93.1	240.7	410.6
M_5	1,310.5	44.7	995.0	102.7
CD (p=0.05)	0.55	0.45	0.67	4.01

Refer to methodology for treatment details.

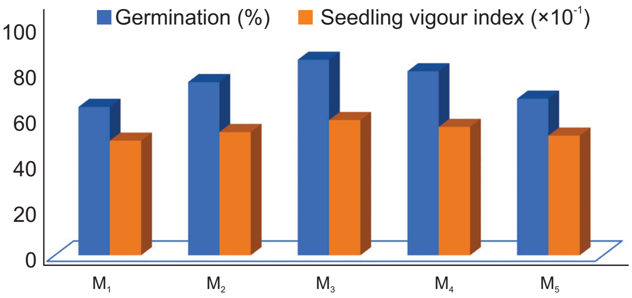

Fig. 1 Effect of growing media on germination percentage and seedling vigour index of fenugreek microgreens. CD (p=0.05): Germination = 0.86%; Seedling vigour = 0.96. Refer to methodology for treatment details.

length) (Abdul-Baki and Anderson 1973), seedling height, shoot density, fresh weight, dry matter, days to first true leaf and fresh yield (g/m²). Germination percentage and seedling vigour index were assessed separately for each growing medium using 200 seeds/treatment under controlled conditions. Moisture and ash contents were determined as per AOAC (2000) and nitrate content by the salicylic acid method (Cataldo *et al.* 1975). Data were analysed using ANOVA for factorial CRD (Gomez and Gomez 1984) and treatment means were compared at $p \leq 0.05$ using LSD.

The physico-chemical properties of growing media varied considerably (Table 1), influencing the root-zone environment and subsequent seedling performance. Bulk density was highest in soil (M_1) (1,435.5 kg/m³) and lowest in sawdust (M_3) (180.5 kg/m³), while total pore space showed an opposite trend, being maximum in sawdust (M_3) (93.1%) and minimum in M_1 (38.8%). Water-holding capacity was highest in M_3 (530.2%), followed by M_4 (410.6%) and lowest in soil (M_1) (60.5%). Media with lower bulk density and higher porosity, such as cocopeat and sawdust, provide improved aeration and moisture retention, creating favourable conditions for seed imbibition and root growth. Similar findings have been reported by Kyriacou *et al.* (2020), Di Gioia *et al.* (2017) and Paglialunga *et al.* (2023), emphasising the role of substrate physical properties in enhancing microgreen growth through improved water retention and gaseous exchange.

Growing media significantly affected germination percentage and seedling vigour index (Fig. 1), with M_3 recording the highest germination (85.65%) and vigour index (592.08) followed by M_4, whereas M_1 exhibited the lowest values. The superior performance of cocopeat and sawdust can be attributed to their favourable physical properties, including higher porosity and water-holding capacity, which enhance oxygen availability and metabolic activity during germination (Shukla *et al.* 2021, Gupta *et al.* 2023). These conditions promote efficient radicle emergence and seedling establishment, resulting in higher vigour. Similar studies on mustard microgreens under hydroponic systems have highlighted the role of nutrient environment and bio-priming in enhancing early establishment and metabolic activity (Khan *et al.* 2025a, Khan *et al.* 2026) and corroborated the superiority of soilless substrates over soil for microgreen production (Pathania *et al.* 2022, Paglialunga *et al.* 2023).

Growth and biomass attributes of fenugreek microgreens were significantly influenced by growing media, seed density and their interaction (Table 2). Cocopeat (M_3)

Table 2 Effect of growing media and seed density on growth and biomass of fenugreek microgreens

Growing medium	Seed density (g/tray; 10 inch × 20 inch tray size)											
	Shoot fresh weight (mg/shoot)			Shoot dry matter (%)			Days to 1st true leaf stage			Seedling Height (cm)		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
M_1	72.5	89.9	82.4	6.6	6.7	6.6	12	12	13	5.1	5.4	4.7
M_2	82.6	102.0	92.4	6.5	6.7	6.4	12	11	12	5.8	6.3	5.5
M_3	90.5	110.1	96.6	6.4	6.6	6.3	10	9	10	6.7	7.2	6.5
M_4	86.5	104.0	94.9	6.5	6.6	6.4	11	10	11	6.2	6.7	5.8
M_5	79.3	96.0	87.0	6.7	6.8	6.6	14	13	13	5.5	5.8	5.2
Mean	82.4	100.4	90.6	6.5	6.7	6.5	11.8	11.1	11.8	5.9	6.3	5.5
CD (p=0.05)	D = 0.72	M = 0.93	D×M = 1.60	D = 0.073	M = 0.094	D×M = 0.016	D = NS	M = 0.94	D×M = 0.74	D = 0.073	M = 0.094	D×M = 0.83

M, Medium; D, Density; NS, Non-significant. Refer to methodology for treatment details.

Table 3 Effect of growing media and seed density on yield and quality parameters of fenugreek microgreens

Growing medium	Microgreen fresh yield (g/m²)			Shoot population density (shoot/m²)			Moisture content (%)			Ash (%)		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
M_1	4,640	6,320	5,444	55,204	61,205	57,200	93.37	93.26	93.42	0.48	0.49	0.45
M_2	5,525	7,209	6,079	61,604	69,599	65,600	93.47	93.33	93.55	0.46	0.45	0.45
M_3	6,019	8,805	6,800	69,600	68,004	75,200	93.63	93.44	93.72	0.35	0.38	0.28
M_4	5,605	7,933	6,404	66,005	74,800	68,800	93.53	93.38	93.62	0.42	0.43	0.42
M_5	4,925	6,523	5,879	59,209	64,405	60,803	93.28	93.18	93.36	0.52	0.53	0.48
Mean	5,342	7,358	6,121	62,324	70,002	65,521	93.45	93.31	93.53	0.45	0.46	0.42
CD (p=0.05)	D = 23.54	M = 30.39	D×M = 52.64	D = 22.47	M = 29.01	D×M = 50.26	D = NS	M = NS	D×M = NS	D = NS	M = NS	D×M = NS

M, Medium; D, Density. Non-significant. Refer to methodology for treatment details.

recorded the highest shoot fresh weight (99.1 mg/shoot), seedling height (6.8 cm) and earliest attainment of first true leaf stage (10 days), followed by sawdust, while soil recorded the lowest values. Seed density of 25 g/tray (D_2) proved optimal, producing maximum fresh weight (100.4 mg/shoot) and height (6.3 cm), whereas higher density (30 g) reduced growth due to competition. The interaction effect showed maximum performance in cocopeat at 25 g (fresh weight 110.8 mg/shoot; height 7.2 cm). Shoot dry matter varied marginally (6.4–6.8%), indicating limited influence of treatments. The superior performance of cocopeat may be attributed to improved aeration, moisture availability, nutrient uptake and physiological efficiency, as also reported in mustard microgreens where optimised nutrient conditions and *Trichoderma* bio-priming enhanced morpho-physiological traits and biomass accumulation (Khan *et al.* 2025a, Khan *et al.* 2026) and corroborated by earlier studies (Di Gioia *et al.* 2017, Kyriacou *et al.* 2017, Poudel *et al.* 2023).

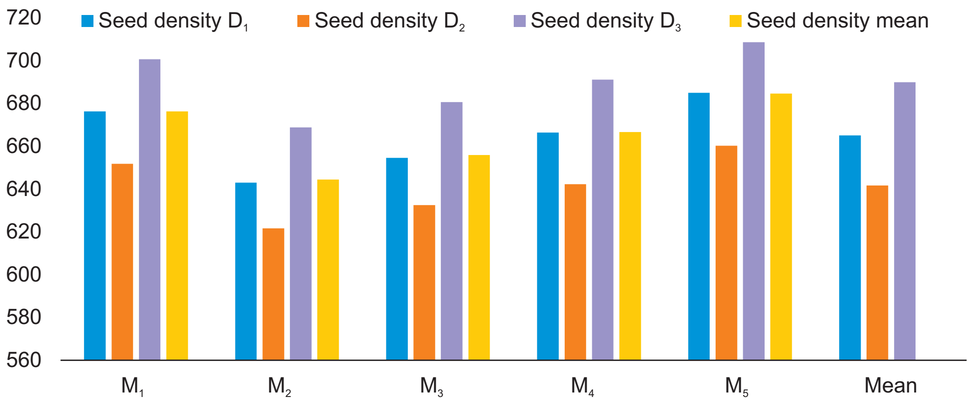

Fig. 2 Effect of growing media and seed density on shoot nitrate content (mg/kg FW) of fenugreek microgreens.
CD (p=0.05): D = 16.19, M = 20.90, D × M = 19.84. M, Medium; D, Density. Refer to methodology for treatment details.

Fresh yield and shoot population density followed trends similar to growth attributes (Table 3). Cocopeat recorded the highest yield (7,208 g/m^2) and shoot population (70,935/m^2), followed by sawdust and blotting paper, while soil produced the lowest fresh yield (5,468 g/m^2) and shoot population (57,870/m^2). Among seed densities, 25 g/tray resulted in maximum yield (7,358 g/m^2), whereas further increase to 30 g did not improve yield despite higher shoot population, indicating intra-specific competition. The interaction effect showed maximum fresh yield (8,805 g/m^2) in cocopeat at 25 g. Moisture (93.18–93.72%) and ash content (0.28–0.53%) were not significantly affected, suggesting stability of these quality traits across treatments. These results agree with earlier studies (Di Gioia *et al.* 2017, Paglialunga *et al.* 2023, Khan *et al.* 2025a, Khan *et al.* 2026), emphasising the importance of substrate and density optimisation.

Shoot nitrate content was significantly influenced by both factors (Fig. 2), with highest values recorded in soil + vermicompost [684.55 mg/kg fresh weight (FW)] and at higher seed density (30 g), while blotting paper and moderate density (25 g) recorded the lowest levels (621.53 mg/kg FW). The interaction revealed maximum nitrate accumulation (708.56 mg/kg FW) in soil + vermicompost at 30 g and minimum in blotting paper at 25 g.

Higher nitrate levels in nutrient-rich media (soil + vermicompost) may be attributed to greater nitrogen availability, whereas increased density likely reduced nitrate assimilation due to competition and limited light interception. Similar nitrate accumulation patterns have been reported in mustard microgreens under varying nutrient strength and microbial treatments by Khan *et al.* (2025a) and Khan *et al.* (2026), consistent with previous reports that nitrate accumulation is governed by substrate nutrient status and crop management practices (Paglialunga *et al.* 2023).

SUMMARY

A study conducted during 2022–23 at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir showed significant effects of media on germination, growth and yield of fenugreek. Cocopeat recorded the highest germination (85.65%), vigour, shoot fresh weight and yield (7,208 g/m^2), followed by sawdust, while soil performed poorest. Seed density of 25 g/tray was optimal, whereas 30 g reduced performance due to competition. Moisture and ash content were unaffected. Nitrate content was highest in soil + vermicompost and at 30 g density, indicating effects of substrate nutrient status and plant density. The study concluded that cocopeat with 25 g/tray seed density may be optimal for fenugreek microgreen production.

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