



Assessment of variability for biochemical and mineral contents in fenugreek germplasm

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Summary

Thirty accessions of fenugreek (*Trigonella foenum-graecum* L.) were investigated for the morphological and proximate composition of (moisture, protein, phenols, total antioxidants and mineral contents) during 2022-2023 and 2023-2024. The genotypes showed a wide range of variations in the biochemical parameters. The fully mature leaves of fenugreek germplasm were subjected to biochemical analysis and revealed a wide range of variability in biochemical traits viz. Protein (3.19 to 5.57%) ascorbic acid content (31.8 to 82.5 µg g⁻¹), phenol content (0.74 to 2.74 mg GAE g⁻¹) and total antioxidants capacity (0.60 to 5.11 mg Trolox/g). EC 510685 was identified for green- copper color leaf with high antioxidant content of leaves ((5.11 mM Trolox/g), EC510717 was found rich in protein (5.5 %) and Zn content (1.12 mg/100 gm). EC510559 was reported to have higher Ca content (360mg/100g-1) while EC510579 was observed with a higher test weight (20.15g). Significant differences were also recorded in mineral content viz. Ca (105 to 360mg/100 gm), Zn (0.34 to 1.2mg/100 gm) and mg (45.7 to 131mg/100 gm). Based on the evaluation superior genotypes identified can be exploited either for the promotion of antioxidants rich fenugreek, coloured leaves genotype for ornamental purposes and minerals-rich genotypes in the processing industry for fortification of fenugreek by developing products with other functional food to overcome malnutrition. This information could also be used to develop antioxidant-rich varieties through a suitable breeding approach.

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Keywords: *Trigonella foenum-graecum* L., variability, protein, mineral content, antioxidant, copper green colour leaf

Introduction

India is known as the home of spices globally due to the production of quality spices over the other countries as blessed with suitable climatic conditions. About 63 spices are grown in our country due to the availability of suitable agro-climatic conditions (Gopal 2018). India exports 0.48 mt (23% of total seed spice production) of raw and value-added products of seed spices to more than 70 countries and earned export revenue to the extent of INR 5,665 crores annually (NRCSS 2021). These crops are primarily grown in arid and semi-arid parts of the country particularly Rajasthan and Gujarat states which are known as "bowls of seed spices". Fenugreek (*Trigonella foenum-graecum* L.) is one of the oldest multipurpose commercially important spice crops mainly cultivated for seeds and leaves and occupies about 72 per cent of the total area and 86 per cent of total production in Rajasthan and Gujarat states only. It is cultivated in Rajasthan, Gujarat, Madhya Pradesh, Uttar Pradesh, Haryana, Himachal Pradesh, Tamil Nadu and Andhra Pradesh (Kaur 2016; Maloo et al. 2020). It is the third major seed spice after cumin and coriander in India popularly known as "Methi" which has been well known

for its aromatic, condiment, carminative, medicinal and pharmacological properties. This diploid (2n=16) crop species is self-pollinated in nature and belongs to the family Fabaceae and sub-family Papilionaceae. The leaves are consumed as green leafy vegetables and seeds are generally used for condiments and flavouring food preparations in India.

In recent days consumers' awareness towards healthy, natural and more sustainable diets attracted attention are an important concern, which needs to be addressed. The so-called healthy food or functional food demand is rising every day. Leafy vegetables are a storehouse of Proteins, dietary fibres, phenol compounds, antioxidants, vitamins and minerals. The antioxidants are known to play a vital role in improving health. If the diet contains more antioxidants, then it is helpful for the prevention of chronic disease. According to research, cancer development is inhibited by antioxidants as the antioxidants remove the oxidation of the given substrate by free radicals (Gall 2011). Currently, the greatest challenge is providing nutritious food to India's ever-increasing population. In the western part of India, particularly Rajasthan, per capita land availability is higher but the effective days of rainfall and total annual precipitation are less, this fruit crop can be substantively used to help combat the undernourishment problem in this post-COVID time. Fenugreek contains Protein, iron, calcium and zinc even more than the regular food items. Its leaves contain good amount of mineral and protein

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content. It is known for its medicinal qualities such as antidiabetic, anticarcinogenic, hypocholesterolemic, antioxidant, and immunological activities. Besides its medicinal value, it is also used as a part of various food product developments as a food stabilizer, adhesive, and emulsifying agent. Fenugreek leaves are rich in Mg, Ca and Fe and The human body requires a number of minerals in order to maintain good health. A number of minerals essential to human nutrition are accumulated in different parts of plants as it accumulate minerals essential for growth from the environment.

ICAR- National Plant Genetic Resources (NBPGR), New Delhi is responsible for the collection, conservation and characterization of genetic diversity of different crop species across the country and documentation for peculiar traits. The NBPGR's regional station for arid region located at Jodhpur is responsible for conserving species belong to hot arid regions of India under MTS in standard cold conditions. The exploration and conservation of spice germplasm is the prime need hour for searching the gene for the crop improvement programme. significant achievements in spices research have been achieved after the characterization and evaluation of fenugreek germplasm conserved in MTS, ICAR-NBPGR, RS, Jodhpur for biotic and abiotic stress tolerance. The germplasm was also evaluated for traits of interest of biochemical parameters. Development of cultivars for early maturity with higher test weight, yield and higher quality are major objectives of the fenugreek breeding programme. Therefore, knowledge of extent and pattern of the existing variability in germplasm of fenugreek was subjected for evaluation during 2022-23 and 2023-24 at NBPGR, RS, Jodhpur for agro morphological and biochemical parameters.

Materials and Methods

The experiment was carried out at the ICAR-NBPGR, Regional Station at Jodhpur (26°15'25.6"N, 73°00'01.9"E), India. All germplasm collected from India and the United States Department of Agriculture (USDA) were evaluated in augmented block design (ABD) during the years 2022-23 and 2023-24 followed by biochemical analysis of superior accession at NBPGR, New Delhi Laboratory. The experimental field's soil was sandy loam, with a pH of 7.95, an organic carbon content of 0.25 per cent, an electrical conductivity of 0.24 dS/m, and accessible phosphorus and potassium concentrations of 47 kg ha⁻¹ and 573.75 kg ha⁻¹, respectively. All recommended agronomic practices were adapted to raising a healthy crop. The data on biochemical-related parameters was recorded on freshly harvested leaves in replicates for each accession. Fully mature leaves, not showing signs of disease and insect attack were selected for recording observations. Analysis of variance was calculated by the method suggested by Panse and Sukhatme (1985). The freshly harvested samples were cleaned in tap water followed by distilled water and then surface dried under the fan using towel paper to remove the adhered water droplets. Fresh samples were immediately analysed for the estimation of moisture and ascorbic acid. Vitamin C estimation was performed using the Folin-phenol reagent method as per (Dani1982) and the results were

expressed in µg/g on a fresh weight basis. The moisture content was determined using the AOAC method 925.10 (Horwitz, 2000; Anu et al. 2019). Cleaned leaves (100 g) were placed in an oven initially at 60 degrees centigrade for overnight drying, then the temperature was raised to 103 ± 2 °C for complete drying until a constant weight was obtained. The dry matter percentage was calculated using the following formula: Dry matter (%) = [(final weight – crucible weight)/initial weight] × 100. The dried leaves were homogenised using a Foss Cyclone mill equipped with a 1 mm sieve and homogenised flour was used for further biochemical evaluation and results were calculated back to fresh weight basis as per moisture content of the respective sample. The protein content was estimated by the Kjeldahl method (AOAC 984.13) (Horwitz 2000). The homogenised flour of dried leaves was digested as described (Singh et al. 2021; John et al. 2023) and Foss Tecator 2300 Kjeltach Nitrogen Auto analyzer was used for Kjeldhal N distillation and titration. The per cent nitrogen was converted to protein by using Jones factor 6.25.

The sample preparation and estimation for total sugar, phenols and antioxidants was done as described by (Talang et al. 2023). The total soluble sugar was estimated by the anthrone reagent method (Roe, 1955) in 80% ethanolic extract, where 100µl of the extract was dried in a boiling water bath, redissolved in 1 ml denoised water and 3 ml of anthrone reagent was added. Absorbance was measured at 630nm and results were compared against D-Glucose standard solution and expressed as g/100g f.wt. Total phenolic content was estimated spectrophotometrically using the Folin–Ciocalteu reagent (Singleton et al. 1981). Briefly, 100 µL of the sample extract (80% ethanol), 2.9 ml of deionized water, 0.5 ml of Folin–Ciocalteu reagent and 2.0 ml of 20% Na₂CO₃ solution were added. The mixture was allowed to stand for 90 min and absorption was measured at 760 nm against a reagent blank in UV–Vis double beam spectrophotometer (Benchtop, USA). Results were expressed as gallic acid equivalent (mg GAE/g f.wt.).

The antioxidant activity was measured by the FRAP (ferric reducing antioxidant power) assay as per Benzie and Strain (1996) with some modifications using 300 mM acetate buffer at pH 3.6, 10 mM TPTZ (2, 4, 6-tripyridyl-s-triazine) in 40 mM HCl, and 20 mM FeCl₃.6H₂O solution. Results are expressed in mg/g f.wt. Trolox equivalent. Minerals namely calcium (Ca), magnesium (Mg), iron(Fe) and zinc (Zn) were estimated as per AOAC, 999.11 (Horwitz 2000). Five hundred milligrams of each sample were digested in nitric acid using a Milestones microwave digester and the digested sample was made into 50 ml solution using denoised water. Mineral concentrations were estimated by Agilent AAS240FS and compared against CRMs of respective minerals.

Results and Discussion

The analysis of variance over the years indicating the mean sum of squares showed highly significant differences among the genotypes for all the traits under study (Table 1,2&3). It indicates that germplasm lines are

genetically diverse from each other and there is huge scope for selection of characters from this germplasm collection for fenugreek improvement programme. Data presented in Tables 1,2,3&Figure 1 indicated a wide variability among the quantitative and qualitative parameters for each accession showed significant ($p < 0.05$). The plant height of the fenugreek genotypes significantly showed statistical differences when grown under the same conditions in 2023 and 2024. Plant height ranged between 27.68 ± 0.7 and 68.94 ± 2.4 cm. Likewise Leaf color also showed differences. It was revealed that the whole germplasm of fenugreek showed variation as light-green (34.23%), green (31.36%), dark-green (31.26%) and copper-green color (3.15%) (Table 1). The duration from the seed sowing to harvesting was observed from 93 ± 2.1 to 120.00 ± 0.5 days in all germplasm studied. Mean values for the number of

branches/plants were 3.7 to 9.8 and seed yield/ plant were 3.15 to 13.52 respectively. As presented in fig1 (b) EC510579 was reported with a maximum test weight of 20.15g [seed length (5.03 mm) & seed width (1.6mm)] as compared to the ruling fenugreek variety AFG-1 (14.95gm). The protein content varied from 3.19 to 5.57 % (Table 2). The highest protein content was found in EC 510559 (5.57%) which belongs to *Trigonella caerulea* species Fig 1(b) while the lowest content was reported from accession EC510689 (3.19 %). High amounts of protein in leaves play an important role to use of leaves for processing and developing value-added products besides of use as green fodder for animals. The results revealed that IC 510559 of fenugreek can be used as a potential source of protein for further use in functional food and products. Such findings are in line as those reported by Ali et. al (2012) and Paricha & Gupta (2014).

Table 1. Phenotypic variability of fenugreek germplasm

Character	Range		Promising accession	Value of best checks
	Min	Max		
Green-copper leaf			EC510685	Green (Afg-2)
Days to 50% flowering (Days)	39	61	IC0624520 (39), EC510678 (40 days), EC510664 (43)	48
Early 80 % maturity (Days)	93	128	IC0624520 (93 days)	120
Plant height (cm)	27.68	68.92	EC510725 (68.26), EC510559 (87.4), EC510724 (67.66), EC510588(66.8),	62.7
No of branches per plant	3.7	9.8	EC510559 (10), EC510633 (8), EC510588 (8), EC510593 (9)	6.12
Test weight (1000 seed) (gm)	11.25	20.15	EC510579(20.15), EC510631 (17.62), EC510613 (17.57), EC510595 (17.53), EC510598 (17.07)	Afg-1 (14.95)

Table 2. Variations in physico-chemical parameters (fresh weight basis) of 30 accessions of fenugreek during 2022-23 and 2023-24

Treatments	Protein (%)			Ascorbic Acid (ug/ g ⁻¹)			Total Phenol (mg GAE g ⁻¹)			Total Antioxidants (mM Trolox/g ⁻¹)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
EC-510662	4.62	4.67	4.64	64.7	63.8	64.2	0.933	0.887	0.910	0.05	0.08	0.065
IC-510559	5.10	5.12	5.11	53.6	55.0	54.3	0.759	0.812	0.786	0.13	0.1	0.115
EC-510588	5.09	5.11	5.10	39.5	40.0	39.8	0.703	0.780	0.741	0.6	0.53	0.565
EC-510741	4.00	4.10	4.05	45.9	45.2	45.5	0.920	0.714	0.817	0.71	0.74	0.725
IC-0624520	3.48	3.51	3.50	49.3	48.3	48.8	1.24	1.25	1.24	2.22	2.52	2.37
EC-510573	4.69	4.66	4.67	40.3	38.4	39.4	1.82	1.86	1.84	0.27	0.26	0.265
EC-510576	4.52	4.46	4.49	45.9	42.5	44.2	2.01	2.10	2.06	1.19	1.42	1.305
EC-510578	3.92	3.98	3.95	42.9	41.3	42.1	1.64	1.65	1.65	1.18	0.85	1.015
EC-510579	3.96	3.92	3.94	34.9	33.5	34.2	1.69	1.72	1.71	0.81	0.88	0.845
EC-510594	3.56	3.66	3.61	53.2	52.4	52.8	2.51	2.10	2.31	1.31	1.52	1.415
EC-510607	4.46	4.55	4.51	35.6	34.8	35.2	2.13	2.10	2.11	1.97	2.31	2.14
EC-510608	3.71	3.70	3.70	36.8	33.6	35.2	1.86	1.76	1.81	2.73	2.45	2.59
EC-510616	3.82	3.84	3.83	44.9	42.6	43.8	2.09	1.98	2.03	2.29	2.81	2.55
EC-510617	4.19	4.24	4.21	59.8	55.0	57.4	2.52	2.54	2.53	3.79	4.05	3.92
EC-510633	4.30	4.26	4.28	44.1	41.6	42.9	0.855	1.120	0.987	2.72	2.83	2.775
EC-510588	3.22	3.20	3.21	32.7	31.8	32.2	1.91	1.98	1.95	0.25	0.43	0.34
EC-510652	4.59	4.60	4.59	41.5	40.5	41.0	2.15	2.16	2.15	0.09	0.05	0.07

EC-510658	5.53	4.50	5.01	49.4	45.5	47.4	2.49	2.52	2.51	1.37	2.05	1.71
EC-510664	4.73	4.72	4.72	52.4	50.5	51.5	1.78	1.80	1.79	2.03	2.16	2.095
EC-510671	4.31	4.32	4.31	50.9	45.2	48.0	2.43	2.60	2.52	1.6	1.84	1.72
EC-510678	5.57	5.56	5.57	46.3	40.2	43.3	1.99	2.00	2.00	0.06	0.08	0.07
EC-510685	3.19	3.32	3.25	32.9	38.5	35.7	2.60	2.88	2.74	5.05	5.17	5.11
EC-510689	3.17	3.20	3.19	54.2	51.4	52.8	2.37	2.20	2.29	0.67	0.53	0.6
EC-510701	4.56	4.25	4.41	46.8	44.8	45.8	2.15	2.10	2.12	1.34	1.67	1.505
EC-510704	4.59	4.60	4.59	53.2	50.5	51.8	2.04	2.10	2.07	1.91	1.78	1.845
EC-510712	5.15	5.10	5.12	79.4	70.0	74.7	2.12	1.89	2.00	2.62	2.92	2.77
EC-510717	4.60	5.40	5.00	82.8	80.0	81.4	1.95	1.66	1.81	2	2.14	2.07
EC-510561	3.99	4.00	3.99	40.2	40.0	40.1	0.886	0.887	0.887	2.43	2.52	2.475
EC-333183	4.80	4.78	4.79	48.4	45.0	46.7	1.69	1.23	1.46	1.26	1.62	1.44
Check (Afg 2)	3.17	3.87	3.52	32.68	35.00	33.84	0.70	0.80	0.75	2.29	2.26	2.275
Mean	4.36	4.63	4.49	48.4	46.3	47.3	1.80	1.77	1.79	1.53	1.66	1.60
CD at 5%	0.27	0.31	0.26	4.25	3.86	4.29	0.24	0.23	0.24	0.30	0.32	0.31

The vitamin c content of the genotypes ranged from 31.8 to 82.5 $\mu\text{g/g}$. EC-510717 reported with highest vitamin C possession (82.5 mg). Higher content of vitamin C not only improves photosynthetic pigments and the antioxidant defense system in plants but also improves the human immune system by more absorption of iron. Phenol content was found in a range of (0.74 to 2.74 mg GAE g^{-1}). The total antioxidant capacity values of fenugreek genotypes were determined by the DPPH and FRAP methods. The findings of examined properties and statistical significance are compared in Table 2 & Fig.1(a). The total antioxidant capacity was found in the range of (0.60 to 5.11 mg Trolox/g). The highest total antioxidants were recorded from the accession EC51068517 (5.11 mg Trolox/g) which contained attractive copper green leaf colour compared to check

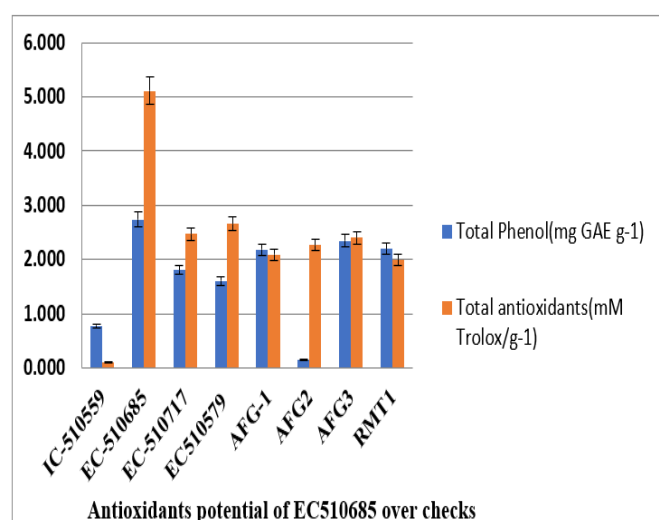
Afg 2 (2.27 mg Trolox/ g^{-1}) having green colour leaves only. The accession EC510685(5.11 mg Trolox/g) was followed by EC 510633 (2.27), and EC 510664(2.09) respectively in term of antioxidant contents. Minimum antioxidants content was reported from EC510652 whereas EC 510685 exhibited about 56 percent higher number of total antioxidants over the ruling cultivar of Afg2. It is a well well-known fact that antioxidants in plants decrease the risks of chronic diseases such as cancer and heart disease (Vinson et al.1998) similar findings are also reported by Mashker (2014) and Urasat *et al* (2014) respectively. The different results of total phenol and total antioxidants can be explained due to differences in leaves and seed part content besides genotype differences, cultivation applications and ecological conditions.

Table 3. Variations in mineral contents (fresh weight basis) of 30 accessions of fenugreek during 2022-23 and 2023-24

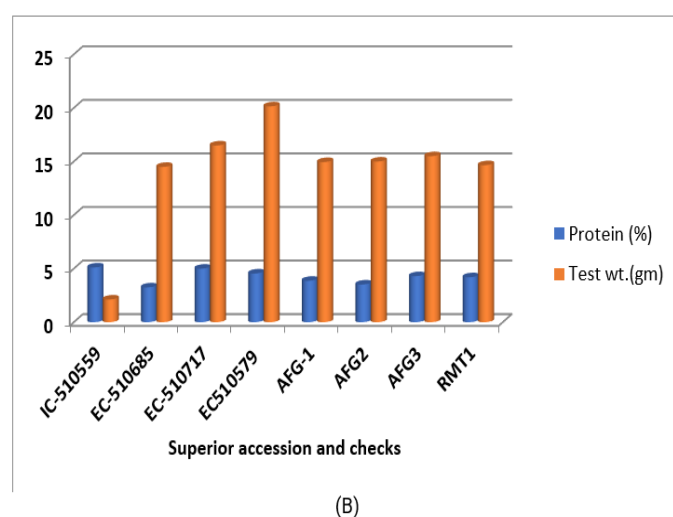
Treatments	Calcium (mg/ 100g ⁻¹)			Zinc (mg/ 100g ⁻¹)			Iron (mg/ 100g ⁻¹)			Magnesium (mg/ 100g ⁻¹)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
EC-510662	110	130	120	0.606	0.610	0.608	5.98	5.88	5.93	76.8	74.6	75.7
IC-510559	390	330	360	0.774	0.724	0.749	4.95	4.96	4.95	58.6	60.2	59.4
EC-510588	168	178	173	0.651	0.625	0.638	4.97	4.88	4.93	62.1	63.4	62.7
EC-510741	107	103	105	0.381	0.389	0.385	4.21	4.36	4.29	55.4	50.2	52.8
IC-0624520	370	270	320	0.548	0.578	0.563	4.33	4.42	4.38	142	120	131
EC-510573	322	300	311	0.735	0.788	0.761	6.11	5.98	6.05	93.2	94.0	93.6
EC-510576	261	252	257	0.532	0.566	0.549	4.48	4.31	4.40	48.5	50.2	49.3
EC-510578	252	230	241	0.461	0.456	0.458	5.86	5.70	5.78	58.2	52.4	55.3
EC-510579	237	245	241	0.405	0.406	0.406	3.97	3.80	3.88	45.1	46.3	45.7
EC-510594	296	245	271	0.510	0.522	0.516	4.31	4.56	4.44	56.2	55.2	55.7
EC-510607	260	234	247	0.349	0.342	0.345	5.63	5.10	5.37	46.5	45.2	45.8
EC-510608	290	320	305	0.472	0.475	0.474	5.61	5.12	5.37	67.7	60.5	64.1
EC-510616	299	297	298	0.514	0.572	0.543	5.28	5.44	5.36	56.0	55.0	55.5
EC-510617	302	300	301	0.398	0.412	0.405	3.72	4.10	3.91	54.7	50.0	52.4

EC-510633	169	150	159	0.603	0.612	0.608	5.81	5.20	5.51	74.8	72.0	73.4
EC-510588	256	244	250	0.461	0.466	0.464	3.88	3.70	3.79	62.6	60.0	61.3
EC-510652	261	230	246	0.784	0.799	0.791	6.04	5.88	5.96	65.6	62.0	63.8
EC-510658	281	270	275	1.118	0.880	0.999	6.56	5.10	5.83	59.5	55.0	57.2
EC-510664	256	240	248	0.537	0.566	0.551	4.40	4.20	4.30	65.1	53.2	59.1
EC-510671	277	260	269	0.597	0.612	0.604	5.97	5.44	5.70	63.4	62.1	62.7
EC-510678	310	280	295	1.106	1.100	1.103	7.52	5.00	6.26	61.2	60.1	60.6
EC-510685	300	320	310	0.402	0.512	0.457	6.42	7.55	6.99	72.4	75.6	74.0
EC-510689	290	280	285	0.756	0.874	0.815	6.07	5.44	5.76	66.8	60.2	63.5
EC-510701	313	312	312	0.676	0.688	0.682	5.5	4.0	4.8	60.0	60.2	60.1
EC-510704	326	310	318	0.557	0.661	0.609	6.96	3.78	5.37	52.8	52.1	52.5
EC-510712	248	250	249	0.625	0.625	0.625	3.89	3.80	3.84	48.9	48.7	48.8
EC-510717	203	210	207	1.120	1.110	1.115	5.15	5.00	5.08	50.7	51.3	51.0
EC-510561	149	150	149	0.506	0.566	0.536	4.76	5.00	4.88	61.6	60.2	60.9
EC-333183	279	280	279	0.363	0.425	0.394	5.64	4.00	4.82	52.9	51.1	52.0
Check (Afg 2)	106	256	181	0.35	0.56	0.45	3.72	4.51	4.11	45.09	88.00	66.55
Mean	261	249	255	0.597	0.610	0.603	5.31	4.89	5.10	63.4	60.7	62.1
CD at 5%	54.88	52.46	53.57	0.10	0.12	0.11	1.34	1.31	1.33	26.42	25.66	25.80

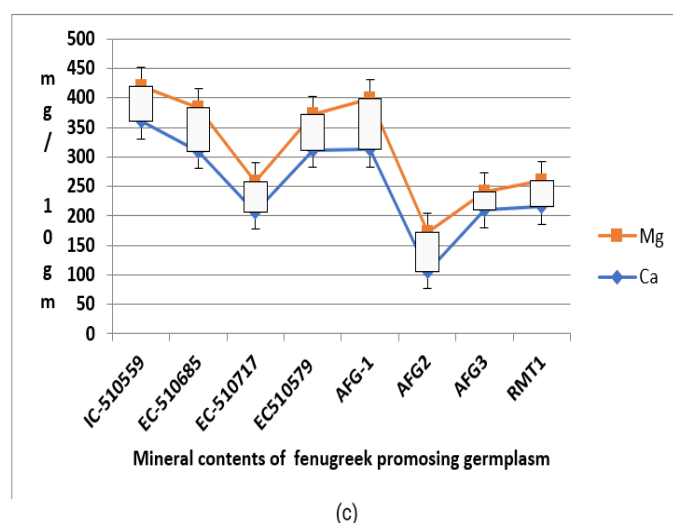
As outlined in Table 3 and Fig (c) mineral profile was evaluated by appreciable amounts of calcium (105 to 360 mg/100g), Zinc (0.34 to 1.11mg/100g), Iron (3.79 to 639 mg/100g) and magnesium (45.7 to 131 mg/100g). The highest content of calcium was reported from genotype EC510559(360) followed by EC510573(311) and EC510685(310). Zn content in different genotypes was found significantly different and the highest amount was recorded from EC510717(1.11) followed by EC510678(1.10) respectively. An appreciable amount of iron was observed from EC510685 whereas the maximum content of magnesium was recorded from IC 624520 followed by EC510573.



(A)



(B)



(C)

Figure 1. (A) Antioxidant potential of IC510685 (b) Protein and test weight of superior accession (c) Mineral content in superior accession

Conclusion

Based on genetic variability study and biochemical analysis of fenugreek germplasm, it can be concluded that a considerable amount of variation exists in agromorphological traits, protein, antioxidant activity and mineral content in fenugreek germplasm studied (*T. foenum-graecum* & *Trigonella caerulea*). Based on two-year findings it can be concluded that the following superior accessions show the richness of trait-specific parameters belonging to *T. foenum-graecum* species such as higher test weight EC510579 (20.15g), higher total antioxidants EC 510685 (5.11 mg Trolox/g) with copper green color leave can be a potential source of developing functional food or for commercial utilization of fenugreek in industries. It can also be used for ornamental purposes due to the attractive color of its leaves. EC510559 genotype belonging to *T. caerulea* found rich in protein content (5.57%) could be utilized for quality improvement of a breeding programme for the development of fodder rich fenugreek variety.

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Declaration of interests

The authors have no conflict of interest to declare.

Data Sharing

All relevant data are within the manuscript

References

1. Ali MA. 2012. Characteristics of oils and nutrient contents of *Nigella sativa* Linn. and *Trigonella foenum-graecum* seeds. *Bull. Chem. Soc. Ethiop.* 26 (1): 523. <https://doi.org/10.4314/bcse.v26i1.6>.
2. Annual Report. 2021. ICAR-National Research Centre on Seed Spices, Tabiji, Ajmer- 305 206 Rajasthan, India
3. Anu UV, Geethalakshmi I, Rajamani K & Uma D. 2019. Nutritional and nutraceutical properties of different plant parts of fenugreek (*Trigonella foenum-graecum* L.). *Journal of Agriculture and Ecology*, 8: 30–37.
4. AOAC, Official method of analysis of the Association of Official Analytical Chemists, Washington, DC, USA, 1990, 15th edn.
5. Arivalagan M, Roy TK, Yasmeen AM, Pavithra KC, Jwala PN, Shivasankara KS, Manikantan MR, Hebbar KB & Kanade SR. 2018. Extraction of phenolic compounds with antioxidant potential from coconut (*Cocos nucifera* L.) testa and identification of phenolic acids and flavonoids using UPLC coupled with TQD-MS/MS. *LWT Food Sci. Tech.*, 92, 116–126
6. Burton GW. 1952. Quantitative inheritance in grasses. *Proceedings, 6th International Grassland Congress*. 1: 277-285
7. Gall A & Shenkute Z. 2009. "Ethiopian Traditional and Herbal Medications and their Interactions with Conventional Drugs". *EthnoMed*. University of Washington.
8. Gopal L. 2018. Scenario, Importance and Prospects of Seed Spices: A Review. *Curr Inves Agri Curr Res* 4(2). CIACR.MS.ID.000181. DOI: 10.32474/CIACR.2018.04.000181.
9. Johnson HW, Robinson HF & Comstock RE. 1955. Estimation of genetic and environmental variability in soybeans. *Agronomy Journal*. 47: 314-318.
10. Kaur L. 2016. Tolerance and accumulation of lead by fenugreek. *Journal of Agriculture and Ecology*, 1: 22–34.
11. Maloo SR, Sharma R, Jain D, Choudhar, S & Soan H. 2020. Assessment of genetic diversity in fenugreek (*Trigonella foenum-graecum*) genotypes using morphological and molecular markers. *Indian Journal of Agricultural Sciences*. 90 (1): 25–30.
12. Mashkor IMAA. 2014. Phenolic content and antioxidant activity of fenugreek seeds extract. *Int. J. Pharmacogn. Phytochem. Res.* 6, 841–844.
13. Panse VG & Sukhatme PV. 1985. Statistical Methods for Agricultural Workers. 2nd Edn. Indian Council of Agricultural Research, New Delhi.
14. Pasricha V & Gupta RK. 2014. Nutraceutical potential of Methi (*Trigonella foenum-graecum* L.) and Kasuri methi (*Trigonella corniculata* L.). *J. pharmacogn. phytochem.* 3(4): 852 (2014).
15. Ranganna S. 1986. Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw Hill Publishing Co. Ltd., New Delhi. 190-210.
16. Shad MA, Pervez H, Zafar IZ, Nawaz H & Khan H. 2012. Physicochemical properties, fatty acid profile and antioxidant activity of peanut oil. *Pak J Bot.* 44: 435-440.
17. Singh D, Gupta H, Kumar L & Sharma S. 2021. Studies on effect of cutting and intra row spacing on leaf and seed yield of fenugreek (*Trigonella foenum-graecum* L.). *Journal of Agriculture and Ecology*, 12: 74–79.
18. Singleton VL, Orthofer R & Lamuela-Raventos RM. 1999. Analysis of total phenols other oxidation substrates and antioxidants by means of Folin–Ciocalteu reagent. *Methods Enzymol.* 299: 152–178.
19. Urasgungor SS, Guzel S, Ilcim A & Kokdil G. 2014. Total phenolic and flavonoid content, mineral composition and antioxidant potential of *Trigonella monspeliaca*. *Turk. J. Pharm. Sci.*, 11: 255–262.
20. Vinson JA, Hao Y, Su C & Zubic L. 1998. Phenol antioxidant quantity and quality in foods: Vegetables. *J. Agric. Food Chem.*, 46: 3630–3634.