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Performance of Fenugreek (*Trigonella foenum-graecum* L.) Genotypes towards Growth, Yield and UPOV Properties

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ABSTRACT

Background: Genetic diversity is referred to the diversity present within different genotypes of same species, serves as the most valuable reservoir in providing variability for various traits. This variability would provide a basis for improving the crop in breeding program. The present study aimed to assessment of genetic diversity and selection of superior genotypes for fenugreek breeding.

Methods: In this study, 75 fenugreek genotypes with cultivars (Çiftçi and Güraslan) were used and these genotypes were established in augmented trial design. Each genotype was analyzed for morphological and yield traits and nineteen traits were scored according to the International Union for the Protection of New Varieties of Plants (UPOV).

Result: As a result of the study, PI 568215 and PI 577712 were noted as promising genotypes for seed yield and protein content, respectively. Dendrogram analysis showed that same origin genotypes were found in different main groups. Correlation analysis revealed that 22 positive or negative correlations were found among the examined properties. PCA analysis results were found among the examined properties and total variation was noted as 39.95%.

Key words: Fenugreek, Genetic diversity, Morphological and yield properties, PCA analysis.

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an annual herb of the Leguminosae family, genus Trigonella, which comprises 36 species. Fenugreek can be grown under a wide range of climatic conditions extending widely to the warm temperate and South East Asia, Japan, Central Asia (Mongolia), wide parts of Africa and South America are significant fenugreek growers (Giridhar *et al.,* 2016).

Fenugreek seeds contain various bioactive compounds like flavonoids, saponins, amino acids, alkaloides. These bioactive compounds are used against allergies, appetite, bronchial, cholesterol, diabetic retinopathy, gas, gastric disorders, lung infections, mucus excessive, cancer, uterine problems *etc*. (Sharangi *et al*., 2005).

Although fenugreek may grow a wide range of conditions and can even be grown on marginal lands in profitable way, genetic diversity among different genotypes should be developed the new strategies for improving its biomass and nutritional and functional elements.

The main reason for this is that despite the large collections of germplasm in Gene banks worldwide, there is not enough information about the genetic diversity and characterization of these species. To address this issue, it is necessary to analyze the genetic diversity of the present germplasm in gene banks. Furthermore, assessment of genetic diversity is crucial to preserving the natural diversity required for the adaptation and selection of superior genotypes for fenugreek breeding (Mondini *et al*., 2009).

Therefore, the objectives of this study were (i) to study the extent of genetic variability of fenugreek genotypes obtained from USDA and (ii) to estimate the extent of association in morphological and yield parameters and thereby compare the direct and indirect effects of the characters on yield.

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MATERIALS AND METHODS

Study area

The study was conducted in the experimental field of Field Crops of the Agriculture Faculty (40°44′44″ N, 31°37′45″ E and an altitude of 881 meters) in 2018. Average climatic data were recorded 17.10°C temperature, 53.68 kg/m^2 rainfall, 71.18% humidity during the vegetation period for 2018 (Yaldiz and Camlica, 2019). Soil properties of experimental fields were as follows: rich in phosphorus (23.74 kg/da), potassium (38 kg/da) and organic matter (%1.6), clay-loam and slightly alkaline (pH: 7.5) (Yaldiz and Camlica, 2021).

Experimental materials and design

75 fenugreek genotypes with cultivars (Çiftçi and Güraslan) were used and these genotypes were established in augmented trial design on April 15th (2018).

Each genotype was analyzed for morphological and yield traits and nineteen traits were scored according to the International Union for the Protection of New Varieties of

Plants (UPOV), in which the qualitative traits were expressed in discontinuous states, while the expression of each quantitative trait was divided into a number of discrete states for the purpose of description (Table 1).

As the base fertilizer, DAP (diamonium phosphate) was added at the rate of 6 kg/da and 4 kg/da ammonium sulfate (AS) fertilizer application was applied. It was top dressed with AS to supply 50 per cent of recommended dose of nitrogen at 30 days after sowing (Çamlıca and Yaldız, 2019). These genotypes were harvested at physiological maturity from last of july to early August. The seeds were separated by hand threshing.

Statistical analysis

Results were subjected to analysis of variance and minimum, maximum, mean, standard deviation, least significant differences and coefficient of variation were determined in fenugreek cultivars and genotypes by using XLSTAT and JMP statistic programs($p<0.05$). Also, dendrogram, correlation and PCA analysis were used to determine relationship among the traits (Çamlıca and Yaldız, 2019).

RESULTS AND DISCUSSION

The results of ANOVA analysis and examined properties were given in Table 2 and Fig 1. The character days to 50 per cent flowering ranged from 45.18-70.18 days, while cultivars (Gürarslan and Çiftçi) began flowering between 56.27 and 57.09, respectively. The earliest flowering day was recorded under India (PI 532867) genotype whereas, the latest flowering day was recorded in Iran (PI 141725) genotype. When genotypes were grouped on the basis of number of days to flowering, 84.42% were early (45.18-58.18 days) and 15.58% were late flowering (58.18-70.18 days) with baseline of 50% flowering days (Table 2).

Plant height of fenugreek cultivars and genotypes changed between 26.48-105.63 cm. The highest plant height was found in PI 639185 genotype and followed by PI 296394 genotype with 100.03 cm. The lowest plant height was found from PI 628790 genotype and followed by PI 244291 genotype with 30.58 cm. The obtained results were found partly similar with Çamlica and Yaldiz (2019) and Mamatha *et al.* (2017) who reported between 24.95-85.15 cm and 67.07-121.23 cm, respectively.

The number of branches per plant ranged from 0.66 to 7.06. The maximum number of branches was recorded in PI 1141725 and PI 532863, while the minimum number of branches was recorded in genotype Australia (PI 613632) and Bulgaria (PI 617078).

The data pertaining to number of pods per plant, which ranged from 0.49 to 77.69, showed significant difference among the fenugreek cultivars and genotypes. The highest pods per plant was recorded in genotype PI 661009, followed by PI 661011 (63.09 number) and PI 173820 (59.79 number), respectively. These results are in line with those obtained by Wojo *et al.* (2015) recorded that number of pods per plant ranged from 16.4 to 22.6.

There was a large variation among the fenugreek cultivars and genotypes in terms of seed number per plant. It ranged from 0.12 to 507.01 number. The most seed number was found in Australia (PI 628790) genotype, which was followed by Iran (PI 296394-444.32 number) and the least seed number was obtained from PI 572540 genotype, which was on par with Iran (PI 229793-0.17 number), Pakistan (PI 426973-0.20 number) and Bulgaria (PI 617078-0.22 number). It can be see that 21 fenugreek genotypes were found higher and 49 genotypes were seen lower than cultivars.

The examined fenugreek cultivars and genotypes had significant seed yield per pod (0.01-0.26 g). Ethiopia (PI 194020) and Egypt (PI 343170), Armenia (PI 639185) had the highest seed weight and followed by Bulgaria (PI 617076) and Pakistan (PI 269994) genotypes, respectively.

There was a significant difference for the number of seeds per pod, ranging from 4.00 to 19.50 (Table 2). The most seed number per pod was obtained from Gürarslan cultivar and followed by PI 639185 (16.30 number) and PI 269993 (15.70 number). The least seed number per pod was found in PI 381062 genotype and PI 628970 genotype with a 4.04 number.

Of the 77 germplasms evaluated, maximum 1000 seed weight was recorded in Jordan (PI 628790-29.04 g) followed by Palestinian (PI 661007-28.37 g) and Syria (PI 572540-27.27 g) genotypes, minimum 1000 seed weight was recorded in Turkey (PI 170834-5.26 g) and followed by India (PI 532867-7.53 g) and Pakistan (PI 543072-9.30 g) genotypes. Thus, 44 genotypes were found higher and 31 genotypes were found lower compared with cultivars in terms of 1000 seed weight.

Seed yield showed wide variation among the fenugreek genotypes in Table 2. Seed yield values changed between 0.05-8.61 g per plant. The maximum seed yield was found in Turkey (PI 568215) genotype and followed by Pakistan (PI 426973-8.28 g) and Armenia (PI 639185-6.67 g) genotypes. The minimum seed yield was determined in Iran (PI 229793-0.05 g) genotype. Compared with cultivars, 20 genotypes were seen higher, 26 genoytpes were found lower and other genotypes were found between seed yield of cultivars. These results are in agreement with the results of Patahk *et al.* (2014), they indicated that the yield per plant ranged from 2.97-10.02 g. By contrast, Mamatha *et al.* (2017) reported the yield per plant ranged from 8.49 to 26.20 g which was higher than this result.

Pod length changed between 7.99-16.13 cm. The maximum pod length was found in PI 661009 genotype and followed by PI 577713 and PI 195854 genotypes with 16.03 cm. The minimum pod length was obtained from PI 532862 and followed by PI 212124 (8.79 cm) and PI 170834 (9.11 cm).

Pod width was ranged from 3.11-4.77 mm. The highest pod width was found in PI 268434 genotype and the lowest pod width was seen in PI 567879 genotype. Compared with genotypes, cultivars were found higher than 15 genotypes and lower than 27 fenugreek genotypes.

Table 1: Characteristics of fenugreek genotypes according to UPOV information.

Qualitative/quantitative or pseudo-qualitative characteristic	Code	State	Note	Qualitative/quantitative or pseudo-qualitative characteristic	Code	State	Note
Basal shape of first leaf blade	UPOV-1	Acute	3	Size of leaf on full grown terminal leaf for length and width (L/W)	UPOV-9	Small in length and width	3
		Obtuse	5			Small in length but wider	5
		Rounded	7			Large length but narrow	7
Apex shape of first leaf blade	UPOV-2	Acute	3			Larger and wider	9
		Obtuse	5	Basal shape of leaf blade on first primary branch axis	UPOV-10	Acute	3
Size of leaf on first primary branches axis for lengthand width (L/W)	UPOV-3	Small in length and width	3			Obtuse	5
		Small in length but wider	5	Apex shape of leaf blade on fully grown terminal leaf	UPOV-11	Acute	3
		Large length but narrow	7			Obtuse	5
		Larger and wider	9	Number of primary branches	UPOV-12	Less (<6)	3
Basal shape of leaf blade on first primary branch axis	UPOV-4	Acute	3			More (>6)	
		Obtuse	5	Plant growth pattern	UPOV-13	V type	3
Apex shape of leaf blade on first primary branch axis	UPOV-5	Acute	3			U type	5
		Obtuse	5	Plant growth habitat	UPOV-14	Determinate	3
		Rounded	7			Indeterminate	5
Size of leaf on first pod axis for lenght and width (L/W)	UPOV-6	Small in length and width	3	Plant height	UPOV-15	Short (<45 cm)	3
		Small in length but wider	5			Tall (>45 cm)	5
		Large length but narrow	7	Pod/plant	UPOV-16	Low (<50 cm)	3
		Larger and wider	9			High (>50 cm)	5
Basal shape of leaf blade on first pod axis	UPOV-7	Acute	3	Pod length (cm)	UPOV-17	Short (<11)	3
		Obtuse	5			Medium (11-12)	5
Apex shape of leaf blade on first pod axis	UPOV-8	Acute	3			Long (>12)	7
		Obtuse	5	Pod curvature	UPOV-18	Moderately curved	3
		Rounded	7			Strongly curved	5
				1000 seed weight	UPOV-19	Low (<16 g)	3
						Medium (16-18 g)	5
						High (>18 g)	7

Table 2: ANOVA analysis of 75 fenugrek genotypes and two cultivars

Properties	Minimum	Maximum	Mean	SD	LSD (5%)	CV (%)
% 50 FD (day)	45.18	70.18	53.88	4.66	7.03	5.35
PH (cm)	26.48	105.63	65.54	14.99	17.9	11.84
NB (No)	0.66	7.06	4.20	1.19	2.06	19.96
PdN (No)	0.49	77.69	33.94	14.51	20.89	25.82
PlntSN (No)	0.12	507.01	177.36	112.85	177.5	35.03
PdSN (No)	4.00	19.50	9.05	3.08	5.25	23.34
1000 SW (g)	5.26	29.04	18.22	4.96	10	24.23
PdSY (g)	0.01	0.26	0.16	0.06	0.08	20.42
PlntSY (g)	0.05	8.61	3.40	1.69	3.17	38.69
PdL (cm)	7.99	16.13	12.14	1.81	4.13	14.19
PdW (mm)	3.11	4.77	4.05	0.38	1.01	10.88
MD (day)	94.95	114.95	105.84	3.89	6.77	2.74

50% FD: 50% flowering days, PH: Plant height, NB: Number of branch, PdN: Pod number, PdSN: Seed number per pod, PdSN: Pod Seed number, 1000 SW: 1000 seed weight, PdSY: Pod Seed yield, PlntSY: Seed yield per plant, PdL: Pod length, PdW: Pod width, MD: Maturity days.

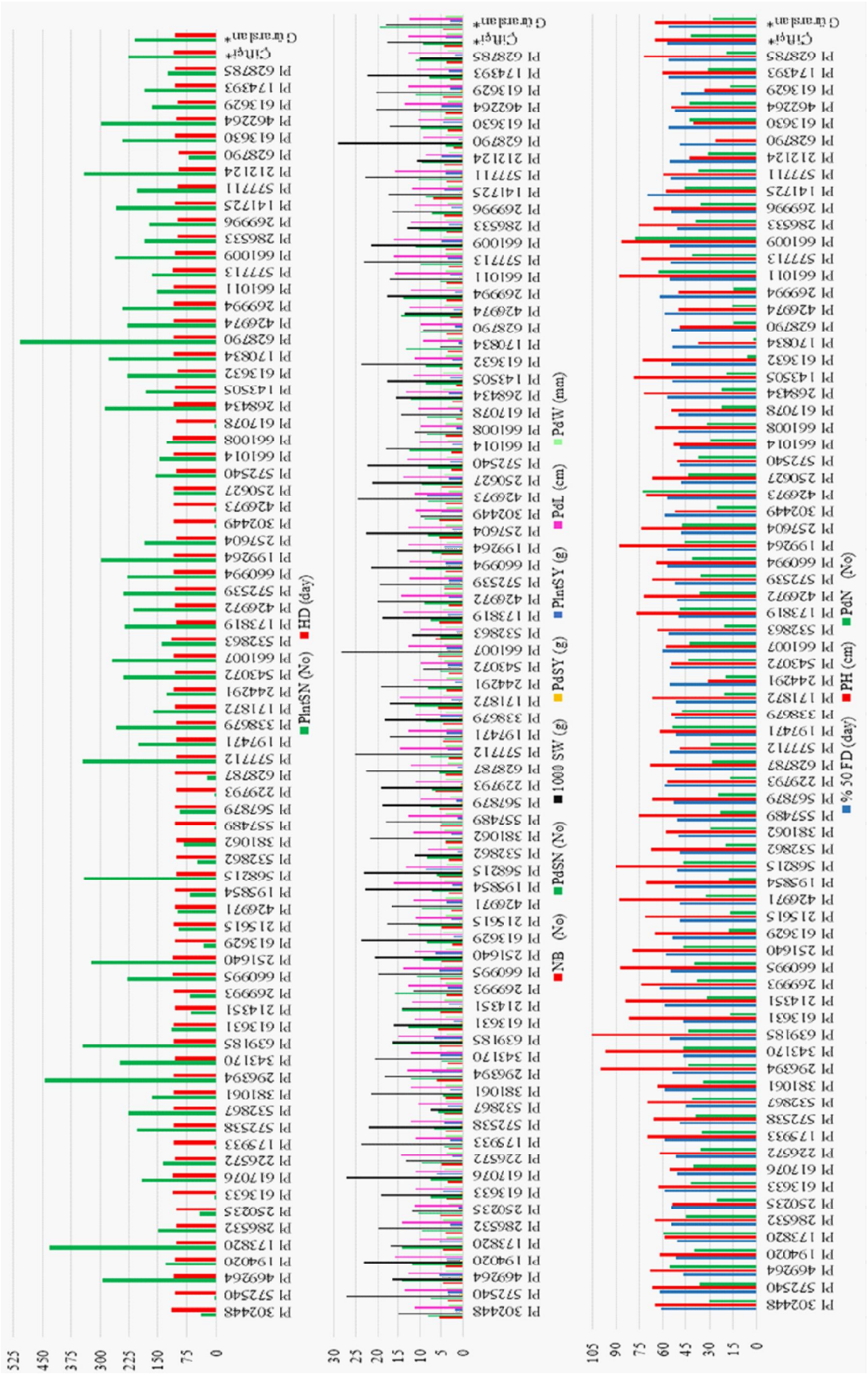

Fig 1: Morphological and yield properties of fenugreek genotypes.

There were significant differences for maturity days among the fenugreek cultivars and genotypes. It varied from 94.95 to 114.95 days. While the earliest maturitiy days were found in Afghanistan (PI 212124) and Jordan (PI 628790) genotypes with 94.95 days, the latest maturity days were obtained from India (PI 302448) genotype and Bulgaria (PI 617076) genotype (112.45 days).

Based on the data obtained from the field trial, the protein contents in selected fenugreek cultivars and genotypes were determined (Fig 2). The protein contents had a large variation between 11.13-33.25%. Morocco (PI 577712) genotype had the highest protein content and followed by Ethiopia (PI 197471-32.41%) and Palestinian (PI 661009-31.73%) genotypes. Whereas Turkey (PI 567879-11.13%), Morocco (PI 338679-12.36%), Bulgaria (PI 617076-12.46%) genotypes had the lowest protein content.

Anitha *et al.* (2016) reported that protein content of fenugreek changed between 8.95-12.90% in different five fenugreek varieties. Aydın *et al.* (2010) reported that protein content changed between 25.40-30.80%. Generally, our results were found partly similar with previous researchers.

Characters of fenugreek cultivars and genotypes were determined according to UPOV criteria as 19 properties. The UPOV criterias showed differences based on fenugreek phenotypic properties. Basal shape of first leaf blade (UPOV-1) was found as acute (3) in 32 genotypes, as obtuse (5) in 30 genotypes and two cultivars. Others were found as rounded (7). Apex shape of first leaf blade (UPOV-2) was determined as obtuse (3) in 52 genotypes and cultivars and other genotypes were observed as rounded (5). Plant growth patern (UPOV-13) was found as V type (3) in 43 genotypes including Gürarslan and other genotypes and Çiftçi cultivar were seen as U type (5). Pod curvature (UPOV-18) were determined in fenugreek cultivars and genotypes as moderately curved (3) and strongly curved (5). It was found 38 genotypes and Çiftçi cultivars as moderately curved and Gürarslan and other genotypes were determined as strongly curved.

The dendrogram analysis were conducted to determine the genetic diversity of fenugreek cultivars and genotypes depending on 12 morphological and yield properties and 19 UPOV criterias (Fig 3). It was divided as two main groups as A and B. A group had 40 genotypes and one cultivar (Çiftçi) and B group included 35 genotypes with one cultivar (Gürarslan). Group A divided two sub-group as A1 and A2. A1 and A2 subgroup contained 12 and 29 genotypes, respectively. Group B was divided two sub-group as B1 (5 genotypes) and B2 (31 genotypes).

The dendrogram analysis results were found similar to reported by Yaldiz and Camlica (2021), Çamlica and Yaldiz (2019), Yaldiz and Camlica (2019) and Camlica and Yaldiz (2021).

Correlation analysis was performed to determine the relationship among the examined properties of fenugreek cultivars and genotypes (Table 3). Totally 22 correlations showed positive or negative effect. There were 13 highly

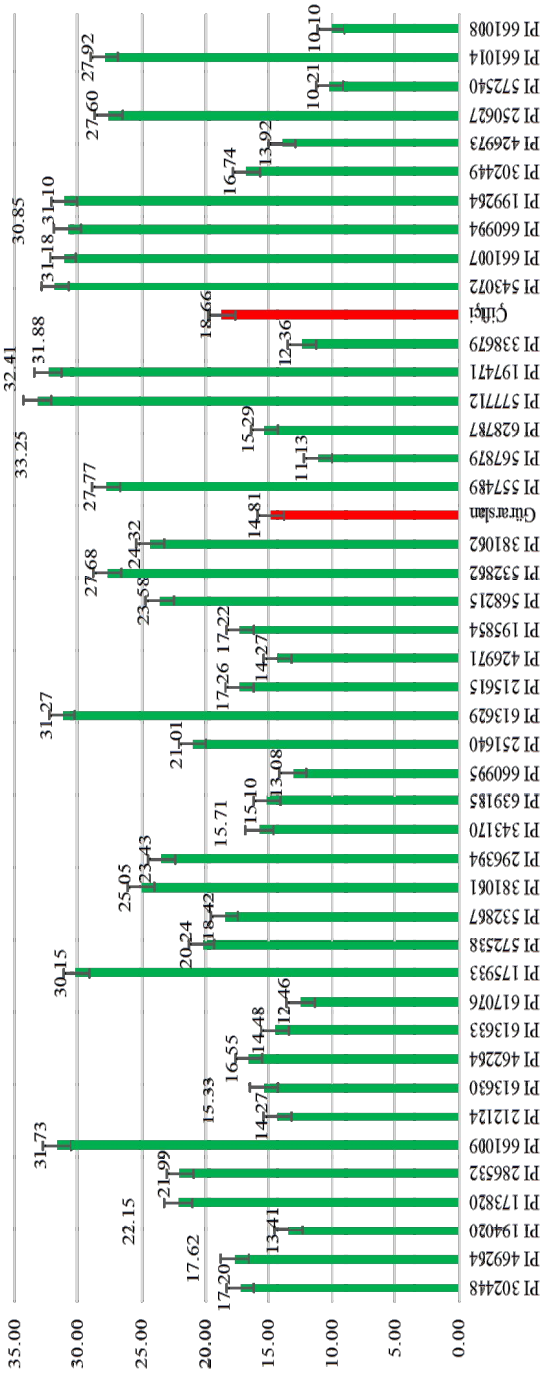

Fig 2: Protein content of selected fenugreek genotypes.

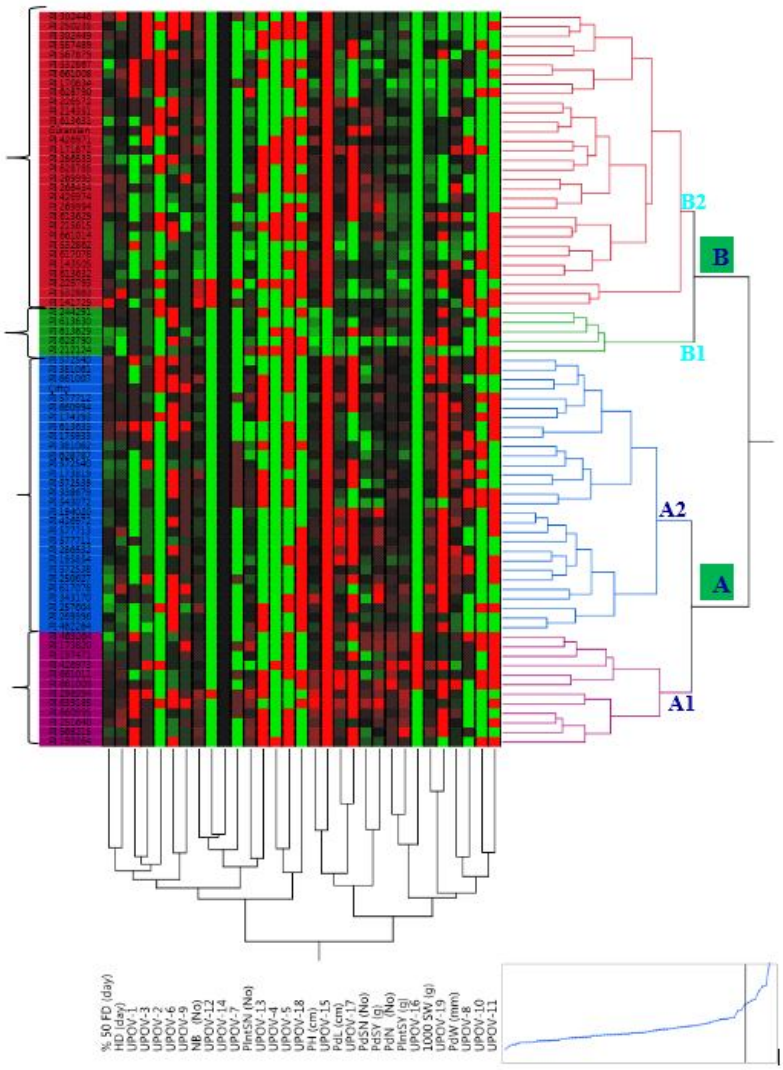

Fig 3: Genetic diversity of fenugreek genotypes.

Table 3: Correlation analysis of fenugreek cultivars and genotypes.

	PH (cm)	NB (no)	PdN (no)	PlntSN (no)	PdSN (no)	1000 SW (g)	PdSY (g)	PlntSY (g)	PdL (cm)	PdW (mm)	MD (day)
50% FD	-0.058	0.161	0.047	-0.025	0.108	-0.012	0.054	0.069	0.058	-0.064	0.332**
PH		0.193	0.41**	0.092	0.063	0.035	0.201	0.386**	0.397**	0.179	0.287*
NB			0.269*	0.094	0.032	-0.144	-0.071	0.194	0.072	-0.189	0.17
PdN				0.251*	-0.067	0.19	0.189	0.705**	0.353**	0.059	0.142
PlntSN					0.255*	-0.105	0.237*	0.463**	0.091	0.135	-0.072
PdSN						-0.299**	0.552**	0.106	0.149	0.011	0.09
1000 SW							0.46**	0.235*	0.375**	0.252*	-0.114
PdSY								0.379**	0.479**	0.209	0.132
PlntSY									0.225*	0.057	0.115
PdL (cm)										0.381**	0.068
PdW (mm)											0.177

*Significant at 5% level, **Significant at 1% level, 50% FD: 50% flowering days, PH: Plant height, NB: Number of branch, PdN: Pod number, PdSN: Seed number per pod, PdSN: Pod seed number, 1000 SW: 1000 seed weight, PdSY: Pod seed yield, PlntSY: Seed yield per plant, PdL: Pod length, PdW: Pod width, MD: Maturity days.

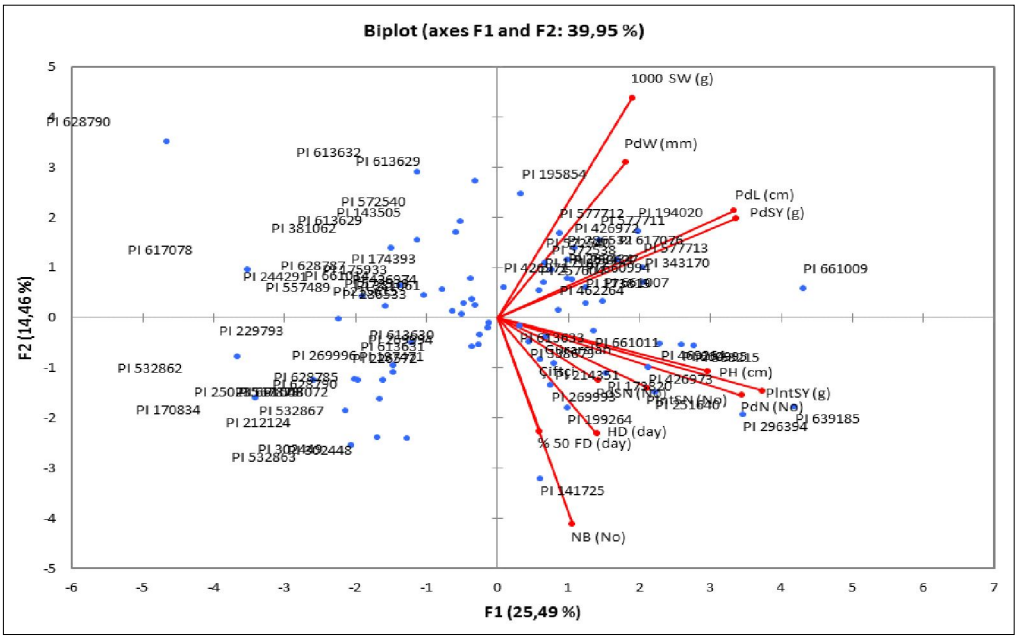

Fig 4: Results of PCA analysis among the examined properties.

significant positive correlations and 8 significant positive correlations. The highest correlations were obtained between pod number and seed yield per plant with r= 0.705 and between pod seed number and pod seed yield with r= 0.552. The highly significant negative correlation was found between pod seed number and 1000 seed weight with r= -0.299.

The present results also agreed with the work of Jain *et al.* (2013) who reported a significant and positive correlation of seed yield with plant height, number of pods on the main axis and the total number of pods/plant. In addition, the positive significant correlations observed between number of branches with numbers of pods are in agreement with the results reported by Bhutia *et al.* (2020).

PCA analysis was carried out to determine the correlation among the examined properties (Fig 4). It revealed that principal component 1 (PC1) accounted for 25.49% of total variation and it was related to pod number and seed yield per plant consisted of PC1 as major factors. PC2 accounted for 14.46% of total variation with branche number and 1000 seed weight were found major factors for PC2.

CONCLUSION

In this study, morphological and yield values and UPOV criteria of different fenugreek cultivars and genotypes were assessed using ANOVA analysis, dendrogram analysis, correlation and PCA analysis. In this context, PI 568215, PI 426973 and PI 639185 genotypes can be selected for seed yield per plant. In addition to seed yield, protein content is an essential factor because of using health benefits for fenugreek. PI 577712, PI 197471 and PI 661009 genotypes can be selected to obtain high protein content for future breeding programs.

Dendrogram analysis showed that fenugreek genotypes had high variation and it was divided into two main groups. Correlation analysis revealed that pod number was highly significant positive correlated with plant seed yield. The PCA analysis was also showed that pod number and plant seed yield were found major factors of PC1. As a result, PI 568215 and PI 577712 genotypes might be good parents to improve seed yield per plant and protein content of fenugreek, respectively.

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