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Exploring Genetic Variability, Correlation and Path Analysis in Fenugreek (*Trigonella foenum-graecum* L.) for Crop Improvement

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ABSTRACT

The present investigation has been carried out at Agricultural Research Station, Mandor, Jodhpur during month of *rabi* season (October, 2016–April, 2017) to evaluate 35 genotypes of fenugreek to assess extent of genetic variability, heritability, genetic advance with correlation and path coefficient for yield and its contributing characters. The material was planted in Randomized Block Design with three replications and observations were recorded on individual plant basis. Analysis of variance recorded significant between genotypes for the characters studies. The genotypic and phenotypic coefficient of variation was higher for seed yield plant^{-1} (g). High heritability (broad sense) coupled with high genetic advance as percentage of mean was observed for branches plant^{-1}, no. of pods plant^{-1}, pod length (cm), seeds pod^{-1}, test weight (g) and seed yield plant^{-1} (g). The correlation analysis at genotypic and phenotypic level, seed yield plant^{-1} was positively significant correlated with branches plant^{-1}, number of pods plant^{-1}, test weight, harvest index, days to 50% flowering, pod length and seeds pod^{-1}, but except days to maturity at phenotype level which was correlated with negative significance. Path coefficient analysis suggested that the highest positive direct effect on grain yield plant^{-1} was exerted by harvest index (%) followed by seeds pod^{-1}, test weight, days to 50% flowering, plant height and branches plant^{-1}. Number of pods plant^{-1}, pod length (cm) and days to maturity contributed considerable negative direct effect on grain yield plant^{-1}.

KEYWORDS: PCV, GCV, heritability, genetic advance, correlation and path analysis

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1. INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) also known as "Methi" is an important leafy vegetable cum seed spices belongs to the sub family Papilionaceae of the family Leguminosae (Ayub, 2019). The place of origin of fenugreek is supposed to be in between Iran and North India (Smith, 1982). The genus Trigonella has two species viz., *Trigonella foenum- graecum* and *Trigonella corniculata. Trigonella foenum-graecum* plants are self-pollinated diploid species with a chromosome number of 2n=16 (Frayer, 1930). It is semi-erect, tall, moderately branched with bold, typically yellow grains (Mamatha and Panyam, 2021). Fenugreek is cultivated mainly in China, India, Turkey, Iran, Argentina, Egypt, Morocco, Southern France, Algeria, Ethiopia & Lebanon (Bose et al., 1993).

Fenugreek is a diploid (2n=16) annual legume plant Ahmad et al. (1999), exhibiting no aneuploidy Petropoulos (2002), Trease and Evans (2002) and (Srivastava et al., 2022). Its stem is elongated and cylindrical, measuring between 30 to 60 centimeters in length and has a pinkish hue. Its roots, as described by Mehrafarin et al. (2011) and Moradi kor and Moradi (2013), are robust and characterized by finger-like structures. In India it is mainly cultivated in Rajasthan, Gujarat, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Himachal Pradesh and Haryana with total area of 218000 hectares with production of 220000 metric tonnes (Anonymous, 2016–17a). It is reasonably tolerant to salinity which makes its suitable for cultivation in major part of the state (Yaldiz and Camlica, 2021); (Demelash, 2023). In Rajasthan mainly cultivated in Sikar, Chittorgarh, Jaipur, Nagour, Jhunjhunu, Kota, Pali, Alwar and Churu districts covering an area of 157004 ha with production of 190362 mt. (Anonymous, 2015–16b).

The productivity of fenugreek is low due to several poor fertility and it have susceptibility to diseases like powdery mildew, wilt, and root rot, which leads to its low productivity (Wilson, 2021). It is the crop in which every part is consumed in one or other forms. Its tender leaves are consumed as leafy vegetables; seed has carminative property and is also an important ingredient of several ayurvedic medicines (Shahrajabian, 2021). Fenugreek seed have anti-oxidant and anti-inflammatory property due to presence of higher amount of secondary metabolic *viz.* flavonoids and phenolic, this crop. Besides this, fenugreek crop also play key role in improving soil fertility (Khursheed, 2023). The fenugreek seed contain carbohydrates (48%), proteins (25.5%), mucilagenous matter (20.0%), fats (7.9%) and saponins (4.8%) (Rao and Sharma, 1987). The seed also contains major nutrients like P and K, minor nutrients like Ca, Fe and Na and amino acid like leucine, valine, lysine and phenylalanine besides cellulose, sapogenin and hemicelluloses (Yadav, 2022). The presence of an alkaloid trigonellin makes its taste bitter. It requires cool climate and dry weather at the time of maturity. It can tolerate frost and high humidity (Burdak, 2020).

Germplasm evaluation studies conducted under AICRP on Spices indicated limited variability for yield and yield associated characters (Reddy and Reddy, 1991). Greater the genetic variability, wider will be the scope for selection in the crop-breeding programme. Heritability specifies the proportion of the genotypic variance to the total phenotypic variance. It is a good index for transmission of characters from parents to the offspring's (Falconer, 1960). High genetic advancement coupled with high heritability estimates offers the most suitable condition for selection (Johnson et al., 1955). Therefore, the analysis of genetic variability and heritability together with genetic advance will be more useful to find out the type of gene action and selection appropriate breeding strategy for better improvement of this crop (Tutlani, 2023). Correlation is useful in disclosing the magnitude and direction of the relationship between various yield contributing traits toward yield. Path coefficient measures the direct effect of a predictor variable upon its response variable and the second component being the indirect effect of a predictor variable (Dewey and Lu, 1959).

2. MATERIALS AND METHODS

The field experiment was conducted at field of ARS Mandor, Jodhpur during *rabi* season (October 2016–April, 2017). The experiment materials carry out with 35 fenugreek of genotypes and grown in Randomized Block Design with three replications. Each entry was grown in row to row and plant to plant spacing are 30×10 cm^2 respectively. Each genotype was planted in an experimental plot size of (4×3 m^2). The recommended package of practices was adopted to raise a healthy crop. The observation on the attributes were recorded on ten plants randomly selected and tagged before flowering from each plot to record the data on plant height (cm), branches plant^{-1}, pods plant^{-1}, pod length (cm), seeds pod^{-1}, test weight (g), harvest index (%) and seed yield plant^{-1} (g) mean values of selected plants were used for statistical analysis while, data on days to 50% flowering and days to maturity were recorded on whole plot basis. The analysis of variance was accomplished as per procedure given by Panse and Sukhatme (1967). These characters were used to analysis phenotypic and genotypic coefficient of variation (Burton, 1952) and (Johnson et al., 1955), heritability (broad sense) (Johnson et al., 1955), correlation (Searle, 1961) and path analysis (Dewey and Lu, 1959).

The variations in phenotype, genotype estimated with the use of analysis of variance. You can calculate the coefficient of variation using these formulae (Burton, 1952).

PCV=√(σ² ph/X)×(100/1)%

GCV=√(σ² g/X)×(100/1)%

Hanson et al. (1956) proposed this method.

$h^2_{(BS)}= (\sigma^2 g/\sigma^2 p)\times100$

$$h^2_{(NS)}=\frac{\frac{1}{2}D+\frac{1}{2}H1-\frac{1}{2}H2-\frac{1}{2}F}{\frac{1}{2}D+\frac{1}{2}H1-\frac{1}{2}H2-\frac{1}{2}F+E} \text{ in (F1)}$$

Where, $_{(BS)}$=Heritability in broad sense

$h^2_{(NS)}$=Heritability in narrow sense

σ^2 g =Genotypic variance

σ^2 p=Phenotypic variance

Johnson et al. (1955) proposed a method to estimate the expected genetic advance by considering genotypic, phenotypic, and heritability factors.

GA=K x $_p$ x h^2

Where, K =Selection intensity (2.06 at 5% level)

σ^2 p=Phenotypic standard deviation

h^2 =Heritability (BS) in fraction

Genetic advance (as % of mean)=(GA/X)×100

Where, GA=Genetic advance

$\bar{X}$ =Mean

The formula recommended by Al-Jibouri et al. (1958) was employed for this computation.

Phenotypic correlation (rp)=)=(PCov(xy))/√(PV(x).PV(y))

Genotypic correlation (rg)= (GCov (xy))/√(GV(x).GV(y))

r_{xy}=(Cov (x,y))/√(V(x)X V(y))

Where, r_{xy}=Correlation coefficient between character x and y,

Cov (x,y)=Co-variance of character x and y

V(x)=Variance of character x

V (y)=Variance of character y

rp=Phenotypic correlation

rg=Genotypic correlation

To determine the significance of correlation coefficients, the estimated values were compared to the tabulated values from Fisher and Yates (1938) using t-2 degrees of freedom at two probability levels: 5% and 1%.

3. RESULTS AND DISCUSSION

The analysis of variance let out that estimated of mean sum of squares for all the characters were high, indicating the large variation amongst the genotypes (Table 1). These results are in accordance with of Datta et al. (2005), Kole and Mishra (2006), Prajapati et al. (2010) and Wojo et al. (2016), Singh et al. (2017)

3.1. Variability viz. GCV, PCV, H^2b and GAM

Higher GCV and PCV observed for seed yield plant^{-1} (g) (Table: 2). This indicated the presence of sufficient amount of genetic variability for these traits that can be exploited by selection for the improvement of characters. These results are in harmony with of Datta et al. (2005), Kole and Mishra (2006), Prajapati et al. (2010) and Wojo et al. (2016), Singh et al. (2017). Moderate GCV and PCV for branches plant^{-1}, no. of pods plant^{-1}, pod length (cm), seeds pod^{-1}, test weight and harvest index (%), which are in agreement with the earlier report of Sarada et al. (2008), Dashora et al. (2013), Jain et al. (2011). Low value of GCV and moderate PCV observed for plant height (cm). Lower GCV and PCV recorded for days to 50% flowering and days to maturity, which indicated that, is selection might not be effective for these characters. Verma and Ali (2012), Kumari et al. (2015) and Singh et al. (2017) also reported similar results.

In present investigation, high heritability observed for days to 50% flowering, plant height (cm), branches plant^{-1}, number of pods plant^{-1}, pod length (cm), seeds per pods, test weight (g), seed yield plant^{-1} (g) and days to maturity indicated are less influenced by environmental factors and are under the control of additive gene effect and selection for improvement for such character would be rewarding. These results are in accordance with the findings of Varma and Kole (2003) for days to 50% flowering, plant height (cm), branches plant^{-1}, number of pods plant^{-1}, pod length (cm), seeds pods^{-1}, test weight (g), seed yield plant^{-1} (g). Moderate

Table 1: Analysis of variance (ANOVA) of yield and its contributing characters in fenugreek

Sources of variation	d.f.	Mean sum of squares									
		DF 50%	PH (cm)	BPP	NPP	PL (cm)	SPP	SP (g)	SYP (g)	DM	HI (%)
Replication	2	1.63	3.08	0.48	7.90	1.37	1.24	0.25	0.37	10.07	12.36
Genotypes	34	48.79**	78.93**	1.00**	38.41**	5.69**	16.07**	19.07**	4.16**	43.14**	69.60**
Error	68	2.72	3.32	0.17	3.55	0.49	0.44	1.01	0.23	3.24	12.96

DF 50%: Days to 50% flowering; PH: Plant height; BPP: Branches plant^{-1}; NPP: No. of pods plant^{-1}; PL: Pod length; SPP: Seeds pods^{-1}; TW: Test weight; SYP: Seed yield plant^{-1}; DM: Days to maturity; HI: Harvest index

Table 2: Genetic parameters for yield and its contributing characters in fenugreek

Characters	Range		General mean	Coefficient of variation		Heritability (%) in broad sense	GA as % of mean
	Min.	Max.		GCV (%)	PCV (%)		
Days to 50 % flowering	49.00	67.00	55.00	7.13	7.73	84.97	13.53
Plant height (cm)	39.97	63.76	51.23	9.80	10.42	88.35	18.97
Branches plant^{-1}	3.09	5.19	3.92	13.47	17.01	62.72	21.98
No. of pods plant^{-1}	20.00	35.67	27.67	12.32	14.08	76.59	22.21
Pod length (cm)	5.49	12.53	10.36	12.71	14.39	77.95	23.10
Seeds pod^{-1}	8.25	18.38	13.76	16.58	17.28	92.14	32.79
Test weight (g)	8.74	17.83	13.74	17.85	19.29	85.68	34.04
Seed yield plant^{-1} (g)	2.07	7.03	5.10	22.45	24.32	85.25	42.70
Days to maturity	112.00	129.00	123.00	2.97	3.31	80.39	5.48
Harvest index (%)	19.71	37.82	27.59	15.75	20.45	59.31	24.98

heritability recorded for harvest index, incanting moderate influence of environment in its phenotypic expression and selection based on performance of traits. These results are in accordance with the findings of Prajapati et al. (2010) and Naik (2012) for harvest index.

The expected genetic advance expressed as percentage of mean was observed to be high for branches plant^{-1}, number of pods plant^{-1}, pod length (cm), seeds pod^{-1}, test weight, seed yield plant^{-1} (g) and harvest index (%). Moderate genetic advance was observed for days to 50% flowering and plant height (cm) and low genetic advance was observed for days to maturity. The results are in accordance with the earlier reports of Sarada et al. (2008) and Joyoti et al. (2017).

Heritability estimates along with genetic gain (genetic advance as per cent of mean) is more useful than heritability alone in predicting the resultant effect for selecting the best individuals (Johnson et al., 1955) and suggesting suitable breeding programme. In present investigation was observed high heritability (broad sense) coupled with high genetic advance as percentage of mean was observed for branches plant^{-1}, no of pods plant^{-1}, pod length (cm), seeds pod^{-1}, test weight (g) and seed yield plant^{-1} (g), which is in agreement with earlier reports of Gangopadhyay et al. (2009), Dashora et al. (2012), Pushpa et al. (2012) and Verma et al. (2016), which indicated in the inheritance of the traits additive gene effects and selection may be effective for these characters.

3.2. Correlation coefficient and path analysis

Correlation coefficient analysis measures the mutual relationship between plant characters and determines the component character on which selection can be made for genetic improvement of yield. In the present investigation, genotypic and phenotypic correlation of seed yield plant^{-1} had positive and significant correlation with branches plant^{-1}, pod length, seeds pod^{-1}, number of pod plant^{-1}, test weight, harvest index and days to 50% flowering. The association of these characters is in the desirable direction and selection for these traits may improve the yield plant^{-1} (Table 3). Similar results were reported by Banerjee and Kole (2004), Sharma and Sastry (2008), Fikreselassie et al. (2012), Pushpa et al. (2012), Singh et al. (2012) and Lodhi et al. (2015). Seeds yield plant^{-1} exhibited positive and non-significant correlation with plant height and days to maturity. Similar results reported by Prajapapati et al. (2010) both characters, Dashora et al. (2011) for plant height, At phenotype level seed yield plant^{-1} had negative and significant correlation with days to maturity which indicated that the character had minimum contribution for increase in yield so direct selection for this character should not be practiced. Most of the characters are associated with each other and the extent of correlation values varies with different characters. Similar results were reported by Prajapati et al. (2010), Singh et al. (2007), Jat (2004).

Path analysis revealed that the direct effects were stronger than indirect effects. Path analysis was carried out by taking seed yield per plant as dependent variable to partition the correlation coefficient into the measures of direct and indirect effects in order to determine the contribution of different characters towards seed yield. Such information would be of great value in enabling the breeder to specifically identify important component traits of yield and utilize the genetic stock for improvement in a planned way. In the present study, path coefficient analysis between the components of fenugreek was worked out.

In present study, Path coefficient analysis revealed that harvest index, number of seed pod^{-1}, test weight, days to 50% flowering, plant height and branches plant^{-1} exhibited positive direct effect on grain yield (Table 4). These results are supported by the reports of Banerjee and Kole (2004) for days to 50% flowering, plant height, seeds per pod and

Table 3: Genotypic and phenotypic correlation coefficient between different characters in fenugreek

Characters	Level	DF 50%	PH (cm)	BPP	NPP	PL (cm)	SPP	TW (g)	SYP (g)	DM	HI (%)
Days to 50 % flowering	G	1	0.0567	-0.0786	-0.1519	-0.1862	-0.2639*	0.0147	0.3457**	-0.0438	0.2860*
	P	1	0.0656	-0.0601	-0.1003	-0.1334	-0.2514*	0.0286	0.3155**	-0.0323	0.2186
Plant height (cm)	G		1	0.2259	0.0270	0.2751*	0.0840	-0.1574	0.009	0.1848	-0.2994*
	P		1	0.1703	0.0526	0.2586*	0.0901	-0.1238	-0.0017	0.1559	-0.2360
Branches plant^{-1}	G			1	0.3666**	0.3055*	0.2997*	0.1948	0.3239**	0.2807*	0.1375
	P			1	0.2741*	0.2248	0.2101	0.1417	0.2229	0.2181	0.0608
Number of pods plant^{-1}	G				1	0.5645*	0.5920**	0.0489	0.3120**	0.1401	0.3065*
	P				1	0.4706**	0.5037**	0.0176	0.2506*	0.0697	0.0685
Pod length (cm)	G					1	0.8190**	0.0325	0.3080**	0.3047*	0.1447
	P					1	0.7193**	0.0272	0.2394*	0.2147	0.0150
Seeds pod^{-1}	G						1	-0.0017	0.3023**	0.3602**	0.1232
	P						1	0.0031	0.2561*	0.3064*	0.0584
Test weight (g)	G							1	0.4574**	-0.3430**	0.2438*
	P							1	0.3942**	-0.29621*	0.1956
Seed yield plant^{-1} (g)	G								1	0.08254	0.7779**
	P								1	-0.0227	0.6368**
Days to maturity	G									1	-0.0058
	P									1	0.0500
Harvest index %	G										1
	P										1

branch per plant, Mahey et al. (2003) and Singh et al. (2005) for number of pods plant^{-1}. However, direct negative effect was observed in characters such as pod number of pods plant^{-1}, pod length (cm) and days to maturity contributed considerable negative direct effect on grain yield plant^{-1}. These results are in accordance with the findings of Prajapati et al. (2010) and Dashora et al. (2011) for days to maturity, Mahey et al. (2003) for plant height (cm) and Dashora et al. (2011) for number of pods plant^{-1}.

Table 4: Path coefficient analysis for yield and its contributing characters in fenugreek -grain yield is as dependent character yield and attributes

Characters	DF 50%	PH (cm)	BPP	NPP	PL (cm)	SPP	TW (g)	DM	HI (%)
Days to 50 % flowering	0.2489	0.0170	-0.0200	-0.0378	-0.0427	-0.0676	0.0046	-0.0185	0.0606
Plant height (cm)	0.0114	0.1680	0.0345	0.0061	0.0452	0.0145	-0.0243	0.0297	-0.0458
Branches plant^{-1}	-0.0091	0.0233	0.1133	0.0372	0.0306	0.0301	0.0200	0.0286	0.0115
Number of pod plant^{-1}	0.0012	-0.0003	-0.0026	-0.0080	-0.0042	-0.0045	-0.0003	-0.0011	-0.0018
Pod length (cm)	0.0032	-0.0049	-0.0050	-0.0097	-0.0184	-0.0143	-0.0006	-0.0052	-0.0017
Seeds pod^{-1}	-0.0841	0.0267	0.0823	0.1733	0.2421	0.3097	0.0001	0.1105	0.0299
Test weight (g)	0.0048	-0.0379	0.0462	0.0097	0.0080	0.0001	0.2615	-0.0828	0.0583
Days to maturity	0.0088	-0.0209	-0.0299	-0.0155	-0.0338	-0.0422	0.0375	-0.1184	-0.0033
Harvest index (%)	0.1482	-0.1658	0.0618	0.1326	0.0547	0.0588	0.1358	0.0169	0.6085
Seed yield plant^{-1} (g)	0.3334	0.0051	0.2805	0.2880	0.2815	0.2846	0.4342	-0.0403	0.7164

4. CONCLUSION

The correlation analysis at genotypic and phenotypic level, seed yield plant^{-1} was positively significant correlated with most of the characters except days to maturity at phenotype level. Path coefficient analysis suggested that the highest positive direct effect on grain yield plant^{-1} was exerted by harvest index (%) followed by seeds pod^{-1}, test weight, days to 50% flowering, plant height and branches plant^{-1}.

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