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Research Article

Genetic variability, character association and path analysis in fenugreek (*Trigonella foenum-graecum* L.) under normal and staggered irrigation regimes

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Abstract
The present study was conducted to identify the nature and magnitude of genetic variability, correlation and path coefficient analysis among forty eight fenugreek genotypes under normal and moisture stress conditions in a randomized block design with three replications. The pooled analysis of variance indicated a significant interaction between genotypes and environments for majority of the traits. The analysis of variance for individual environments indicated the existence of significant variability for all the characters, justifying the selection of genotypes for the study. The values of phenotypic coefficient of variation were higher than the genotypic coefficient of variation indicated effect of environment on expression of all characters. The satisfactory estimates of coefficients of variation were recorded for pods per plant and seed yield per plant. High heritability coupled with high genetic advance as a percentage of mean was observed for pods per plant in both environments. The correlation and path coefficient analysis showed that pods per plant had a positive correlation with a high direct effect on seed yield. The results indicated that selection may be worthwhile for pods per plant due to lesser influence of environment and predominance of additive gene action in the genotypes for increasing seed yield.

Keywords: Correlation, Fenugreek, Genetic Variability, Moisture Stress, Path, Seed Yield

INTRODUCTION

India is known as the "Land of Spices" due to the largest producer, consumer and exporter of spices and spice products, among which, fenugreek (*Trigonella foenum-graecum* L.) is a self-pollinated diploid annual species having chromosome number 2n=16 belongs to the Fabaceae family and the Papilionaceae subfamily. It is believed that the fenugreek (also known by the name "methi") originated from Iran and North India (Smith, 1982). It is extensively cultivated in most regions of the world and in India mainly cultivated in Rajasthan, Madhya Pradesh, Gujarat, Tamil Nadu, Uttar Pradesh, Andhra Pradesh, Haryana and Himachal Pradesh. Rajasthan is accounting for about >80% of fenugreek production in the country have a monopoly in production. Fenugreek has pinnately trifoliate light green leaves, 30 to 90 cm tall with erect growth habit (single stem or branched at base). It has a unique place in the diet as a spice cum vegetable crop due to its taste, flavour and nutritional content (Gadaginmath, 1992). Fenugreek seed contains 48% carbohydrate, 25.5% protein, 20% mucilaginous matter, 7.9% fat and 4.8% saponin (Rao and Sharma, 1987), nutrients like P, K, Ca, Fe, Na, vitamins A, B_1, B_3, C, volatile oils (0.015% n-alkanes and sesquiterpenes) and bitterness in seeds due to "Trigonellin" alkaloid.

Fenugreek has a high degree of medicinal value to use as ayurvedic medicine for curing several diseases. It also has wide use in industrial and pharmaceutical purposes, as for the extraction of a steroid precursor “diosgenin”. Hence, it is used as a natural home remedy and excellent off-season fodder or animal food supplement. Since it is a legume, its roots have “Rhizobium”-containing root nodules. It can be grown under a wide range of climatic conditions. However, bound success is achieved for the improvement of genetic potential due to many limiting factors and majority of cultivation is still dependent on rainfall or conserved moisture, therefore crop suffers moisture stress during the vegetative to reproductive stage. Hence, there is a need to develop new varieties with high productivity for such a harsh condition.

The germplasm is used as the most valuable reservoir to provide variability for various traits that is prerequisite for successful breeding programmes. Yield is a complex quantitative character highly influenced by environmental conditions, resulted in difficult to determine whether the observed variability is heritable or not, for this, heritability is a suitable measure to estimate the heritable genetic portion of the total variability. The estimation of heritability along with genetic advances is generally more useful to provide a clear prediction of the breeding value. Correlation reveals only the direction and magnitude of association between any two traits however the path-coefficient analysis partition the correlation into direct and indirect effects of various components on yield and serves as a powerful tool in the selection procedure accordingly. Therefore, the present study is prompted to detect the genetic variability, correlation and path analysis between different pairs of characters which will help to understand the effects of moisture stress on plant growth and in the evaluation, identification or development of high yielding fenugreek genotypes.

MATERIALS AND METHODS

The experiment was conducted with 48 fenugreek genotypes obtained from the AICRP germplasm collection on Seed Spices at Agronomy Farm, S.K.N. College of Agriculture, Jobner, Jaipur which is situated at an elevation of 420 m above mean sea level 20º 6’ N, 75º 25’ E having dry climate. The Randomized Block Design was used to raise these genotypes during *rabi,* 2016-17 in three replications under two environments namely, (i) normal irrigation (E1) and (ii) moisture stress or staggered irrigation condition (E2). The moisture stress environment was created in a staggered manner by providing half of the irrigations given in the normal environment.

In E1 total of seven irrigations were given at an interval of 15 days except for 6th and 7th schedule where irrigation was given at an interval of 10 days due to the full bloom stage of crop. Thus, in E1 condition, crop received moisture regularly at vegetative, flowering, pod formation, pod filling and pod maturation stages. In E2 total of four irrigations were given at an interval of 15 days in 1st and 2nd irrigation while 3rd irrigation was given at 60 days after sowing which created moisture stress at the flowering and pod formation stage because the irrigation was stopped after 30 days. The 4th last irrigation was given at 85 days which also created some moisture stress during grain filling and grain maturation stage. There was no specific check for the said stress however, a short duration variety RMt-305 was included in the experiment. The stress was assessed using tolerance (TOL), stress susceptibility index (SSI) and other stress indices.

Each genotype was sown in a 3 m length single row plot in each replication/environment. The distance between row to row and plant to plant was maintained at 30 cm and 10 cm, respectively. Five plants were randomly selected to tag before flowering from each plot and observations were recorded on branches per plant, plant height (cm), pods per plant, seeds per pod, pod length (cm), seed yield per plant (g) and 1000-seed weight (g). However, the data on days to 50% flowering and days to maturity were recorded on a whole plot basis. The good and healthy crop was raised by following all recommended packages of practices. Pooled analysis of variance was used to know the genotype x environment interaction. The interaction was significant and hence analysis of variance was performed separately for each environment according to the procedure suggested by Panse and Sukhatme (1985). The formulae utilized to estimate the genetic parameters are cited in **Table 1** and their categorization is presented in **Table 2**. The genotypic and phenotypic correlation coefficient between different pairs of characters were calculated by genotypic, phenotypic and environmental components of variances and co-variances for each environment separately as described by Singh and Chaudhary (1985) and formulae given by Johnson *et al.* (1955). Path coefficient analysis was conducted as suggested by Wright (1921) and worked out by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The pooled analysis of variance indicated that the genotype x environment interaction was significant for all the characters except for days to maturity and days to 50% flowering that showed non linear/differential response of genotypes to the environments (**Table 3**). These results are consistent with the findings of Kole (2005), Kakani *et al.* (2014), Kumari *et al.* (2016) and Meena *et al.* (2017) in fenugreek. The analysis of variance (ANOVA) for each of the environments was carried out separately and found highly significant differences for each of the characters in each of the environments that showed the existence of inherent differences among the genotypes for all the studied characters thus ample amount of genetic variability was present which can be exploited for further improvement of seed yield (**Table 4**). These results are in line with the findings of Ahari *et al.* (2010), Dashora *et al.* (2011) and Meena *et al.* (2017) in fenugreek

Table 1. Estimates of genetic variability

S.No.	Name of the variability estimates	Equation	Reference
1	Genotypic variance (σ^2g)	$(\sigma^2 g) = \frac{MSS(t) - MSS(e)}{\bar{X}} x100$	Lush (1940)
2	Phenotypic variance (σ^2p)	$(\sigma^2 p) = \sigma^2 g + MSS(e)$	Lush (1940)
3	Environment variance (σ^2e)	$(\sigma^2 e) = MSS(e)$	Lush (1940)
4	Genotypic Coefficient of Variation (GCV)	$(GCV) = \frac{\sqrt{\sigma^2 g}}{\bar{X}} X\,100$	Burton (1952); Johnson *et al.* (1955)
5	Phenotypic Coefficient of Variation (PCV)	$(PCV) = \frac{\sqrt{\sigma^2 p}}{\bar{X}} X\,100$	Burton (1952); Johnson *et al.* (1955)
6	Heritability (h^2_{bs}) (%)	$(h^2_{bs}) = \frac{\sigma^2 g}{\sigma^2 p} X\,100$	Lush (1940)
7	Genetic advance (GA)	$(GA) = h^2_{bs}.k.\sigma p$	Johnson *et al.* (1955)
8	Genetic Advance as percentage of Mean (GAM) (%)	$GAM(\%) = (GA/\bar{X} \times 100)$	Johnson *et al.* (1955)

Where, h^2_{bs} = Broad sense heritability; k = selection intensity @ 5% (k = 2.06); σp = Phenotypic standard deviation; $\bar{X}$ = Grand mean of the traits; σ^2g = Genotypic variance; σ^2p = Phenotypic variance; MSS(t) = Mean sum of squares due to treatments; MSS(e) Mean sum of squares due to error.

Table 2. Categorization of genetic estimates

Estimates	Categories			References
	Low	Medium	High	
GCV & PCV (%)	< 10	10-20	> 20	Sivasubramanian and Madhavamenon (1973)
Heritability (h^2_{bs}) (%)	<30	30-60	> 60	Johnson *et al.* (1955)
GAM (%)	<10	10-20	> 20	Johnson *et al.* (1955)

Table 3. Pooled ANOVA for different traits in fenugreek genotypes evaluated under normal (E1) and staggered irrigation (E2) conditions

S. No.	Characters	Source of variation with d.f.				
		Environments (E) (1)	Replications/E (4)	Genotypes (G) (47)	G x E (47)	Error (188)
1	Days to 50% flowering	477.92**	3.84	14.26**	1.49	1.88
2	Days to maturity	1065.68**	4.86	26.80**	3.31	2.60
3	Plant height	13844.21**	7.32	114.49**	12.80*	8.57
4	Branches per plant	27.75**	0.20	0.44**	0.23*	0.15
5	Pods per plant	8504.25**	6.71	119.28**	56.91**	11.59
6	Pod length	79.88**	0.15	0.85**	0.29**	0.10
7	Seeds per pod	179.40**	0.13	4.57**	0.75**	0.29
8	1000-seed weight	129.52**	1.43	2.90**	1.01**	0.54
9	Seed yield per plant	264.68**	1.00	2.96**	2.03**	0.51

* = 5% significance level; ** = 1% significance level

Table 4. Mean squares for different traits in fenugreek under normal (E1) and staggered irrigation (E2) conditions

S. No.	Source of variation	d.f.	Environments	Days to 50% flowering	Days to maturity	Plant height	Branches per plant	Pods per plant	Pod length)	Seeds per pod	1000-seed weight	Seed yield per plant
1	Replications	2	E1	2.80	7.92	2.18	0.19	11.23	0.01	0.06	1.17	0.87
			E2	4.88	1.80	12.46	0.20	2.18	0.28	0.21	1.68	1.12
2	Genotypes	47	E1	8.92**	19.08**	75.80**	0.42**	120.55**	0.59**	2.46**	1.79**	3.74**
			E2	6.82**	11.03**	51.49**	0.25**	55.64**	0.55**	2.86**	2.12**	1.24**
3	Error	94	E1	1.86	2.87	8.10	0.16	13.05	0.08	0.23	0.48	0.61
			E2	1.90	2.33	9.04	0.14	10.13	0.11	0.36	0.60	0.42

** = 1% significance level

under normal conditions, Dhayal and Bhargava (1997) and Singh and Jat (2007) in cumin, Patni (1983) in barley and Sadaqat *et al.* (2003) in rape under normal (E1) and moisture stress conditions.

The mean, range, variances, genotypic and phenotypic coefficients of variation (GCV and PCV), heritability in a broad sense (%) and genetic advance as a percentage of the mean (GAM @ 5%) for different yield and yield related traits of the genotypes under E1 and E2 conditions are presented in **Table 5**. The general mean of the characters was higher in E1 in comparison to E2. Maximum and minimum mean values under both E1 and E2 were observed for days to maturity (102.53 & 98.68 days) and branches per plant (4.96 & 4.34), respectively. The mean values suggested that the selection of desirable genotypes can be effective based on different traits studied. Mean values were decreased under moisture stress in comparison to normal irrigation conditions (**Table 6**). The range was wider for all the traits in E1 in comparison to E2 except for 1000-seed weight. The widest range was recorded for pods per plant (24.53-51.40; 15.53-34.93) and plant height (48.60-72.00; 36.87-57.93) under both the environments, respectively

Table 5. Mean, range, variances estimates, coefficients of variation, heritability (broad sense) and genetic advance for yield and other attributes under normal (E1) and staggered irrigation conditions (E2)

S. No.	Character	Environment	Mean	Range	Estimate of variance		Coefficient of variation (%)		h^2_{bs} (%)	GA as % of mean
					σ^2g	σ^2p	Genotypic	Phenotypic		
1	Days to 50% flowering	E1	47.74	45.00-56.00	2.35	4.21	3.21	4.30	55.82	4.94
		E2	45.16	43.33-53.00	1.64	3.54	2.84	4.17	46.33	3.99
2	Days to maturity	E1	102.53	98.00-111.00	5.40	8.27	2.27	2.80	65.30	3.77
		E2	98.68	95.00-105.33	2.90	5.23	1.73	2.32	55.45	2.64
3	Plant height (cm)	E1	62.98	48.60-72.00	22.57	30.67	7.54	8.79	73.59	13.34
		E2	49.12	36.87-57.93	14.15	23.19	7.66	9.80	61.02	12.32
4	Branches per plant	E1	4.96	4.27-6.27	0.09	0.25	6.04	10.07	36.00	7.45
		E2	4.34	3.73-4.87	0.04	0.18	4.61	9.77	22.22	4.38
5	Pods per plant	E1	37.73	24.53-51.40	35.83	48.88	15.87	18.53	73.30	27.99
		E2	26.86	15.53-34.93	15.17	25.30	14.50	18.73	59.96	23.12
6	Pod length (cm)	E1	10.33	9.40-11.47	0.17	0.25	3.99	4.84	68.00	6.78
		E2	9.28	8.53-10.33	0.14	0.25	4.03	5.39	56.00	6.25
7	Seeds per pod	E1	16.05	13.37-18.40	0.74	0.97	5.36	6.14	76.29	9.66
		E2	14.47	12.53-17.00	0.83	1.19	6.29	7.54	69.75	10.85
8	1000-seed weight (g)	E1	10.96	9.48-12.79	0.44	0.92	6.05	8.75	47.83	8.67
		E2	9.62	7.73-11.93	0.51	1.11	7.43	10.96	45.95	10.40
9	Seed yield per plant (g)	E1	6.71	4.84-9.69	1.04	1.65	15.19	19.13	63.03	24.88
		E2	4.80	3.53-6.18	0.28	0.70	11.03	17.45	40.00	14.39

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Table 6. Percent decrease in the mean performance of different characters under staggered irrigation condition (E2) as compared to normal irrigation condition (E1)

S. No.	Character	Mean		% decrease in the mean
		E1	E2	
1	Days to 50% flowering	47.74	45.16	5.40
2	Days to maturity	102.53	98.68	3.75
3	Plant height (cm)	62.98	49.12	22.01
4	Branches per plant	4.96	4.34	12.50
5	Pods per plant	37.73	26.86	28.81
6	Pod length (cm)	10.33	9.28	10.16
7	Seeds per pod	16.05	14.47	9.84
8	1000-seed weight (g)	10.96	9.62	12.23
9	Seed yield per plant (g)	6.71	4.80	28.46

which indicated the presence of sufficient variability in the studied genetic material that would help to select best genotypes from availing genotypes. However, a narrow range was recorded for branches per plant (4.27-6.27; 3.73-4.87) in both the environments, respectively indicated minimum variation. Hence, less scope for selection in present genotypes. These findings are in agreement with Ahari *et al.* (2010), Meena *et al.* (2017) in fenugreek and Singh and Jat (2007) in cumin.

The PCV was found higher than the corresponding GCV for all the studied characters, which indicated that the expression of character was affected by environment. The estimates of GCV and PCV were higher in E1 than E2 for all the traits except plant height, pod length, seeds per pod and 1000-seed weight. The PCV ranged from 2.80 (days to maturity) to 19.13 per cent (seed yield per plant) in E1 and from 2.32 (days to maturity) to 18.73 per cent (pods per plant) in E2. The GCV ranged from 2.27 (days to maturity) to 15.87 per cent (pods per plant) in E1 and from 1.73 (days to maturity) to 14.50 per cent (pods per plant) in E2. Commonly the change in the mean is associated with higher variation for majority of the characters in stress conditions (Paroda and Chopra, 1986). The satisfactory estimates of coefficients of variation were observed for pods per plant and seed yield per plant in both environments. Thus, selection might be more effective for these traits as the response to selection is directly proportional to the variability that exist in the experimental material. Low estimates of coefficients of variations were observed for pod length, days to 50% flowering and days to maturity in both the conditions indicated that selection might not be influential for these characters. Similar findings were also reported for the high magnitude of GCV and PCV in seed yield and pods per plant by Singh and Jat (2007) in cumin and Meena *et al.* (2017) in fenugreek under both the environments and by Sarada *et al*. (2008a), Kumari *et al.* (2015), Sharma *et al.* (2015) under normal condition. The difference between GCV and PCV values was observed narrow for days to maturity followed by seeds per pod, pod length and days to 50% flowering indicated the least influence of environment (relative tolerance to environmental variation) with the impendence of additive gene action and the present genetic collection can be improved and selected for these traits under stress condition for improvement of moisture stress tolerance. However, the difference between GCV and PCV values was observed high for traits *viz.,* seed yield per plant, pods per plant and branches per plant indicated that variation for these characters was also due to environment and selection based on phenotype may be influenced as their expression also depends on environmental factors. The remaining traits, it was found to be moderate.

Estimates of heritability provide significant guidance to the breeder in assessing the heritable proportion of variation due to the genotypes. When heritability of a character is high (>60%), selection would be fairly easy due to close correspondence between genotypic and phenotypic variation and relatively smaller contribution of the environment to the phenotype, but when heritability of a character is low (<30%), selection may be considered difficult or virtually impractical due to masking effect of environment on the genotypic effect of that character. The broad sense heritability was higher in E1 than E2 for all the characters (**Table 5**). Comparison between the environments for different traits indicated that the high heritability estimates were obtained for seeds per pod (76.29%; 69.75%), plant height (73.59%; 61.02%) and pods per plant (73.30%; 59.96%) while high to moderate heritability was recorded for pod length, days to maturity, seed yield per plant, days to 50% flowering and 1000-seed weight and low heritability estimates was recorded for branches per plant (36.00%; 22.22%) in both the environments, respectively. The considerable changes in heritability between the environments were recorded for seed yield per plant however; a little change was obtained for 1000-seed weight. These findings are in close agreement with earlier reports of Dashora *et al.* (2011) and Meena *et al.* (2017) for plant height and pods per plant in both the environments and by Sarada *et al*. (2008a), Singh (2014), Sharma *et al.* (2015) and Wojo *et al.* (2016) under a normal environment in fenugreek.

Heritability estimates alone do not provide complete information on the amount of genetic progress and Johnson *et al.* (1955) demonstrated that heritability and genetic advance jointly would be more useful for the reliable conclusion of selecting the best genotype. Therefore, genetic advance as a percentage of mean (GAM) was calculated in order to determine the relative merits of different characters that can be further utilized in the selection programme (**Table 5**). Comparison of the genetic advance amid the environments indicated that the high estimates of GAM were recorded for pods per plant (27.99%; 23.12%, respectively) and high to moderate for seed yield per plant, plant height and seeds per pod while the low for pod length, branches per plant, days to 50% flowering and days to maturity in both the environments. The changes were observed considerable for seed yield per plant however, the values varied little across environmental conditions for majority of the characters.

Comparison for the heritability coupled with genetic advance between the environments indicated that pods per plant had high heritability along with high GAM in both the environments which referred to the presence of additive gene action and selection of this character may be effective with ample scope of improvement in the genetic material studied that means if any selection scheme is based on this trait for exploiting fixable genetic variance, a widely adopted genotype can be developed. Whereas, seed yield per plant, plant height and seeds per pod had high to moderate heritability accompanied GAM in both the environments which indicated that their expression is governed by both additive and non-additive genetic effects thus selection should be done in later segregating generations i.e. through hybridization programme. The branches per plant had moderate to low heritability with low GAM in both environments; therefore, selection for this character may not be effective due to the environmental effect. The remaining traits had high to moderate heritability along with moderate to low GAM in both environments indicated the presence of non-additive gene action having environmental influence in its inheritance. Earlier studies have also indicated high heritability with high GAM for pods per plant, plant height and seeds per pod (Sarada *et al.*, 2008 a), pods per plant and seed yield per plant (Patahk *et al.*, 2014; Sharma *et al.*, 2015) in a normal environment and close findings of Dashora *et al.* (2011) and Meena *et al.* (2017) in fenugreek, Singh and Jat (2007) in cumin under both environments.

Selection efficiency is a key attribute in the success of any breeding programme that cannot be applied to a single trait because a majority of the traits are polygenic in nature and influenced by each other. The knowledge of correlation is imperative as it facilitates quick assessment of the characters to bring genetic up-gradation in one by a selection of the other characters that influence the ultimate character, seed yield in this case. Therefore, all possible correlation coefficient values among characters at both phenotypic and genotypic levels were calculated under E1 and E2 and are presented in **Table 7** and **Table 8**, respectively. The information on degree and direction of association between two or more variables is provided by genetic correlation which may be due to genetic (pleiotropic effect or linkage) or environmental causes. Since, there is no tangible test to know the statistical significance of correlation at the genotypic level hence major emphasis has been given to the phenotypic correlation coefficient as significance was tested at only the phenotypic level (Reddy and Sharma, 1982; Singh *et al*., 1998). The difference between genotypic and phenotypic correlation coefficients was negligible. In general, genotypic correlation values were higher than phenotypic correlation values in similar directions at both levels for a majority of the traits indicated a strong inherent association between various characters studied, however, the direction and magnitude of correlation coefficient vary with the genetic material being evaluated.

In E1, the correlation between different characters at phenotypic level, seed yield per plant had a positive significant association with pods per plant (0.783), 1000-seed weight (0.341) and plant height (0.219), whereas the positive and non-significant association with branches per plant (0.108) and pod length (0.066). Similarly, seed yield per plant had a negative significant association with days to maturity (-0.166) and seeds per pod (-0.173), while negative and non-significant association with days to 50% flowering (-0.133). There was good correspondence between the correlation as it followed the almost same pattern in both the environments.

In E2, seed yield per plant had a positive significant association with pods per plant (0.562), plant height (0.426), seeds per pod (0.325), 1000-seed weight (0.282) and pod length (0.238), whereas the positive and non-significant association with branches per plant (0.099). Similarly, days to 50% flowering (-0.168) had a negative significant association and days to maturity (-0.145) had a negative and non-significant association with seed yield per plant. The correlation among the characters *inter se* also revealed a positive or negative significant association with each other in both the environments.

The comparison of association analysis between the environments revealed that seed yield per plant was significantly and positively correlated with plant height, pods per plant and 1000-seed weight in both the environments. The correlation estimates for all other characters were varied with the environmental conditions clearly indicated that character expression of

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genotypes is adversely affected by the moisture stress. Similar findings were reported by Meena *et al.* (2017) for pods per plant in both environments. Reports of Mahey *et al.* (2003), Sarada *et al.* (2008b) and Jain *et al.* (2013) in fenugreek also supported the above findings in a normal environment.

Table 7. Genotypic and phenotypic correlation coefficients between different traits in fenugreek under normal condition (E1)

Character	Correlation	Days to maturity	Plant height	Branches per plant	Pods per plant	Pod length	Seeds per pod	1000-seed weight	Seed yield per plant
Days to 50% flowering	r_g	0.797	-0.619	0.120	-0.262	-0.197	-0.196	0.145	-0.235
	r_p	0.539**	-0.441**	0.044	-0.144	-0.126	-0.135	0.096	-0.133
Days to maturity	r_g		-0.576	0.155	-0.275	-0.123	-0.131	-0.021	-0.175
	r_p		-0.404**	0.027	-0.239**	-0.158	-0.108	-0.056	-0.166*
Plant height	r_g			-0.326	0.274	-0.111	0.004	0.131	0.272
	r_p			-0.160	0.249**	-0.109	0.005	0.055	0.219**
Branches per plant	r_g				0.088	-0.367	-0.332	0.244	-0.018
	r_p				0.096	-0.134	-0.172*	0.245**	0.108
Pods per plant	r_g					-0.104	-0.396	0.137	0.833
	r_p					-0.054	-0.279**	0.116	0.783**
Pod length	r_g						0.580	-0.042	0.061
	r_p						0.404**	-0.055	0.066
Seeds per pod	r_g							-0.256	-0.294
	r_p							-0.156	-0.173*
1000-seed weight	r_g								0.464
	r_p								0.341**

*and** represent significant at P = 0.05 and P = 0.01, respectively and r_g= Genotypic correlation r_p=Phenotypic correlation

Table 8. Genotypic and phenotypic correlation coefficients between different traits in fenugreek under staggered irrigation condition (E2)

Character	Correlation	Days to maturity	Plant height	Branches per plant	Pods per plant	Pod length	Seeds per pod	1000-seed weight	Seed yield per plant
Days to 50% flowering	r_g	0.839	-0.456	-0.343	-0.243	-0.239	-0.417	0.540	-0.420
	r_p	0.545**	-0.275**	-0.148	-0.133	-0.189*	-0.157	0.193*	-0.168*
Days to maturity	r_g		-0.546	-0.311	-0.334	-0.412	-0.038	0.147	-0.302
	r_p		-0.312**	-0.088	-0.232**	-0.242**	0.001	0.100	-0.145
Plant height	r_g			-0.123	0.570	0.270	0.363	0.330	0.709
	r_p			-0.069	0.394**	0.262**	0.254**	0.243**	0.426**
Branches per plant	r_g				-0.147	-0.428	-0.511	-0.580	0.115
	r_p				0.104	-0.150	-0.216**	-0.159	0.099
Pods per plant	r_g					0.205	0.149	0.019	0.694
	r_p					0.129	0.166*	0.111	0.562**
Pod length	r_g						0.369	0.070	0.351
	r_p						0.244**	0.032	0.238**
Seeds per pod	r_g							-0.143	0.417
	r_p							-0.043	0.325**
1000-seed weight	r_g								0.079
	r_p								0.282**

*and** represent significant at P = 0.05 and P = 0.01, respectively and r_g= Genotypic correlation r_p=Phenotypic correlation

The path coefficient analysis gives information about cause and effect situations so it provides more realistic pictures of interrelationships. It is carried out to partition the genotypic and phenotypic correlation coefficients of seed yield with its contributing traits into direct and indirect effects by taking seed yield as a dependent variable and other component characters as independent variables and is presented in **Table 9** and **Table 10** in both genotypic and phenotypic levels, respectively. As such, direct and indirect effects on seed yield at a genotypic level were stronger than the phenotypic level for most of the traits in almost similar directions hence importance was given to the path coefficient analysis at the phenotypic level.

In E1, the results of path coefficient analysis revealed that pods per plant had the highest positive direct effect (0.776) on the seed yield followed by 1000-seed weight (0.277), pod length (0.117), days to maturity (0.111), seeds per pod (0.041) and plant height (0.035). Hence, these characters may be considered as the main components for selection of higher seed yield, whereas days to 50% flowering had the highest negative effect (-0.071) on seed yield followed by branches per plant (-0.006) at phenotypic level (Wojo *et al.*, 2016). The days to 50% flowering, days to maturity and seeds per pod showed high negative indirect effects on seed yield through pods per plant (-0.112; -0.185; -0.217, respectively). Plant height showed a high positive indirect effect through pods per plant (0.193). The indirect effect of other characters was negligible. At the genotypic level, all the characters had a positive direct effect on seed yield except for days to 50% flowering, plant height, pod length and branches per plant. The residual effect was low at both genotypic (0.0737) and phenotypic (0.2992) levels indicated that the studied traits account for almost the whole variation in seed yield per plant.

Path coefficient analysis over two environmental situations revealed the variable contribution of different characters to seed yield with changes in environmental conditions. Changes were noted in the direction and magnitude of direct and indirect effects between the environments.

In E2, the highest positive direct effect on seed yield was exerted by pods per plant (0.419) followed by 1000 seed weight (0.247), seeds per pod (0.233), branches per plant (0.162), plant height (0.118), pod length (0.110) and days to maturity (0.043) therefore, these traits are important for seed yield improvement. The negative direct effect on seed yield was exerted by days to 50% flowering (-0.069) at the phenotypic level. The plant height showed high positive indirect effects on seed yield through pods per plant (0.165). The indirect effect of other characters was negligible. The trend with respect to genotypic path coefficient of seed yield with other characters was more or less the same. The residual effect at genotypic

Table 9. Genotypic and phenotypic path coefficients between different traits in fenugreek under normal condition (E1)

Character	G/P	Days to 50% flowering	Days to maturity	Plant height	Branches per plant	Pods per plant	Pod length	Seeds per pod	1000-seed weight	Correlation with seed yield per plant
Days to 50% flowering	G	**-0.499**	0.310	0.133	-0.035	-0.219	0.009	-0.011	0.078	-0.235
	P	**-0.071**	0.060	-0.015	0.001	-0.112	-0.015	-0.005	0.026	-0.133
Days to maturity	G	-0.398	**0.389**	0.124	-0.045	-0.230	0.005	-0.007	-0.011	-0.175
	P	-0.038	**0.111**	-0.014	0.001	-0.185	-0.019	-0.004	-0.015	-0.166*
Plant height	G	0.309	-0.224	**-0.215**	0.095	0.230	0.005	0.001	0.071	0.272
	P	0.031	-0.045	**0.035**	0.001	0.193	-0.013	0.001	0.015	0.219**
Branches per plant	G	-0.060	0.060	0.070	**-0.292**	0.073	0.016	-0.019	0.133	-0.018
	P	-0.003	0.003	-0.006	**-0.006**	0.075	-0.016	-0.007	0.068	0.108
Pods per plant	G	0.131	-0.107	-0.059	-0.026	**0.837**	0.004	-0.022	0.074	0.833
	P	0.010	-0.026	0.009	-0.001	**0.776**	-0.006	-0.011	0.032	0.783**
Pod length	G	0.098	-0.048	0.024	0.107	-0.087	**-0.043**	0.033	-0.023	0.061
	P	0.009	-0.018	-0.004	0.001	-0.042	**0.117**	0.016	-0.015	0.066
Seeds per pod	G	0.098	-0.051	-0.001	0.097	-0.331	-0.025	**0.057**	-0.139	-0.294
	P	0.010	-0.012	0.001	0.001	-0.217	0.047	**0.041**	-0.043	-0.173*
1000-seed weight	G	-0.072	-0.008	-0.028	-0.071	0.114	0.002	-0.015	**0.542**	0.464
	P	-0.007	-0.006	0.002	-0.001	0.090	-0.006	-0.006	**0.277**	0.341**

Residual effect: Genotypic = 0.0737 Phenotypic = 0.2992, Bold figures indicate direct effects
*and** represent significant at P = 0.05 and P = 0.01, respectively G = Genotypic path coefficient, P = Phenotypic path coefficient

Table 10. Genotypic and phenotypic path coefficients between different traits in fenugreek under staggered irrigation condition (E2)

Character	G/P	Days to 50% flowering	Days to maturity	Plant height	Branches per plant	Pods per plant	Pod length	Seeds per pod	1000-seed weight	Correlation with seed yield per plant
Days to 50% flowering	G	**7.050**	-4.623	1.119	-1.789	-0.427	0.085	-2.856	1.019	-0.420
	P	**-0.069**	0.023	-0.032	-0.024	-0.056	-0.021	-0.037	0.048	-0.168*
Days to maturity	G	5.915	**-5.510**	1.339	-1.623	-0.586	0.147	-0.260	0.277	-0.302
	P	-0.038	**0.043**	-0.037	-0.014	-0.097	-0.027	0.001	0.025	-0.145
Plant height	G	-3.214	3.007	**-2.455**	-0.641	0.999	-0.096	2.487	0.623	0.709
	P	0.019	-0.013	**0.118**	-0.011	0.165	0.029	0.059	0.060	0.426**
Branches per plant	G	-2.418	1.715	0.302	**5.217**	-0.258	0.152	-3.499	-1.096	0.115
	P	0.010	-0.004	-0.008	**0.162**	0.043	-0.017	-0.050	-0.039	0.099
Pods per plant	G	-1.716	1.842	-1.400	-0.767	**1.752**	-0.073	1.020	0.036	0.694
	P	0.009	-0.010	0.046	0.017	**0.419**	0.014	0.039	0.028	0.562**
Pod length	G	-1.685	2.269	-0.662	-2.233	0.360	**-0.356**	2.525	0.133	0.351
	P	0.013	-0.010	0.031	-0.024	0.054	**0.110**	0.057	0.008	0.238**
Seeds per pod	G	-2.940	0.209	-0.891	-2.667	0.261	-0.131	**6.847**	-0.270	0.417
	P	0.011	0.001	0.030	-0.035	0.070	0.027	**0.233**	-0.011	0.325**
1000-seed weight	G	3.807	-0.807	-0.809	-3.028	0.033	-0.025	-0.980	**1.888**	0.079
	P	-0.013	0.004	0.029	-0.026	0.047	0.004	-0.010	**0.247**	0.282**

Residual effect: Genotypic = -0.6561, Phenotypic = 0.5218, Bold figures indicate direct effects
*and** represent significant at P = 0.05 and P = 0.01, respectively G = Genotypic path coefficient, P = Phenotypic path coefficient

(-0.6561) and phenotypic (0.5218) levels was somehow low indicated all the studied characters contributed to seed yield. The correlation and path coefficient analysis studies showed that pods per plant are the most influential trait therefore, direct selection of this trait may be effective for improvement of seed yield per plant. These findings are in accordance with the reports of Gangopadhyay *et al.* (2009), Jain *et al.* (2013), Kole and Saha (2013), Singh (2014) and Meena *et al.* (2017) in fenugreek.

Based on the present investigation, it is concluded that there was a wide range of variation among the genotypes for all the characters that showed considerable scope existed for the improvement of fenugreek cultivars through selection. It is also suggested that selection for pods per plant alone will bring about a definite improvement in seed yield as plants bearing more number of pods per plant give more seed yield. Therefore, in the breeding programme, major emphasis should be given to the pods per plant in both the environmental conditions as it had a higher magnitude of variability parameters and positive correlation with a high direct effect on seed yield. On the other hand, concerted efforts should be given to evaluate a larger number of genotypes that are more likely to identify genotypes worth exploitation in a breeding programme to develop moisture stress tolerant varieties in fenugreek.

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