

EVALUATION OF FENUGREEK (*TRIGONELLA FOENUM -GRAECUM L.*) GENOTYPES UNDER NORMAL AND LIMITED MOISTURE CONDITIONS

R.P. Meena¹, D. Singh¹, B.L. Meena^{2*}, S.K. Meena and R. Kumari

¹*Department of Plant Breeding & Genetics, S.K.N. College of Agriculture, Jobner-303329*

²*ICAR Research Complex for NEH Region, Tripura Centre, Lembucherra - 799210*

Email: blmeena.icar@gmail.com

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Abstract: The present investigation was carried out during rabi 2007-08 at Research Farm, S.K.N. College of Agriculture, Jobner with 60 genotypes of fenugreek (*Trigonella foenum-graecum L.*) in RBD with three replications to estimate the genetic variability, heritability and genetic advance for nine quantitative traits. Analysis of variance indicated significant genetic variability among the genotypes for all the characters in individuals as well as the pooled basis under both the environments. High magnitude of PCV and GCV were observed for seed yield per plant in both the environments. High estimates of PCV, GCV, heritability and genetic advance as percentage of mean were found for seed yield per plant in both the environment. Based on the present investigation it is suggested that in breeding programme major emphasis should be given to pods per plant in both the environmental conditions as it had positive correlation with seed yield per plant with high direct effect. The association analysis revealed that seed yield per plant was significantly and positively correlated with branches per plant, pods per plant and seeds per pod in both the environment. Path coefficient analysis indicated that direct selection for pods per plant in both the environments, was the important character for selection of high yielding genotype as this exerted high positive direct effect as well as showed high and positive correlation with seed yield. Based on the present investigation it is suggested that in breeding programme major emphasis should be given to pods per plant in both the environmental conditions as it had positive correlation with seed yield per plant with high direct effect. On the other hand concerted efforts on evaluation of a larger number of genotypes are likely to identify genotypes worth exploitation in breeding programme to develop limited moisture stress tolerant varieties in fenugreek.

Keyword: *Trigonella foenum-graecum L*, GCV, PCV, Heritability, Genetic advance, Character association, Path coefficient

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum L.*) a member of Fabaceae family, originated from Iran and North India (Smith, 1982). Fenugreek seeds and leaves are strongly aromatic and flavorful. The seeds are bitter in taste, but lose their bitterness if lightly roasted. They are rich in vitamins such as thiamin, folic acid, riboflavin, niacin, vitamins A, B6, and C, and are a rich storehouse of many minerals such as copper, potassium, calcium, iron, selenium, zinc, manganese, and magnesium. Fenugreek leaves are a rich source of vitamin K as well. Fenugreek seeds are a rich source of trigonelline, lysine and 1-tryptophan. The seeds also contain a large amount of saponins and fibers that may account for many of the health benefits of fenugreek. Like reduces cholesterol, regulates blood sugar and controls diabetes, enhances breast milk production, protects from cancer, maintains healthy testosterone levels, aids digestion, helps with weight loss and fenugreek's use as a natural home remedy. Fenugreek is an indispensable spice due to its nutrition value, taste and flavour and has its unique place in the diet as a vegetable cum spice crop (Gadaginmath, 1992). Its seed contains carbohydrates (48%), proteins (25.5%), mucilaginous matter (20.0%), fats (7.9%) and saponin (4.8%) (Rao and Sharma, 1987). Fenugreek

seeds are generally found in most blends of curry powder, spice mixes and meat products. A potential use of fenugreek is for extraction of diosgenin. Diosgenin is a steroid precursor, which is used as a basic material in the synthesis of sex hormones and contraceptives. Fenugreek also has a high degree of medicinal value as it is used in certain Ayurvedic medicines for curing colic, flatulence, dysentery, diarrhoea, dyspepsia with loss of appetite. In addition, it is also used for correcting gastric troubles, regulating digestive system, relief in joint pains particularly of old age and as component of concentrate mixture in cattle feeds.

India is the largest producer, consumer and exporter of fenugreek in the world with an annual production of 121,775 tonnes from 96,304 hectares. (National Horticulture Board, 2011-12). Rajasthan leads the country in its production, productivity and export followed by Gujarat, Madhya Pradesh and Uttranchal (Spices Board, 2016).

The productivity of the crop is low due to many limiting factors such as lack of superior genotypes or improved cultivars for use in breeding programme to develop potential hybrids. So, there is need for development of new varieties and hybrids with high productivity. The critical assessment of nature and magnitude of variability in the germplasm stock is one of the important pre-requisites for formulating effective breeding methods (Krishna et al. 2007). Improvement in any crop is proportional to the

*Corresponding Author

magnitude of its genetic variability present in germplasm. Greater the variability in a population, there are the greater chance for effective selection for desirable types (Vavilov, 1951). Heritability is the portion of phenotypic variation which is transmitted from parent to progeny. Higher the heritable variation, greater will be the possibility of fixing the characters by selection. Hence, heritability studies are of foremost importance to judge whether the observed variation for a particular character is due to genotype or due to environment. Heritability estimates may not provide clear predictability of the breeding value. Thus, estimation of heritability accompanied with genetic advance is generally more useful than heritability alone in prediction of the resultant effect for selecting the best individuals (Johnson et al. 1955).

Therefore, the present investigation was carried out with a view to study the genetic variability, heritability and genetic advance for yield and yield component characters in 60 fenugreek genotypes.

MATERIAL AND METHOD

The experiment was carried out with 60 genotypes (Table 1) of fenugreek at Research Farm, S.K.N. College of Agriculture, Jaipur, Rajasthan, India. The site of the experiment at Jobner. Jobner is situated at an elevation 420 meters above mean sea level at 20° 6' N and 75° 25' E which falls under dry climate. A total of 60 germplasm lines were raised in a Randomized Block Design with three replications in two environments namely, (i) normal and (ii) limited moisture condition. In each environment/replication, each genotype was sown in a plot size 2.0 x 0.3 m² consisting of one row. The row to row and plant to plant distance was 30 cm and 10 cm, respectively. Five competitive plants were selected at random for recording the observations on plant height (cm), branches per plant, number of pods per plant, Number of seed per pod, Pod length (cm), 1000-seed weight (g) and Seed yield per plants (g). Data on days to 50% flowering and Days to maturity was however recorded on whole plot basis. The crop was raised as per the recommended package of practices. Analysis of variance was carried out as per the procedure given by Panse and Sukhatme (1985). Genotypic and phenotypic correlation coefficients of variability were estimated according to the Burton and Devane (1953) by using the following formulae.

$$PCV = \frac{\sqrt{\sigma^2_p}}{\bar{x}} \times 100 \quad GCV = \frac{\sqrt{\sigma^2_g}}{\bar{x}} \times 100$$

Where,

PCV = Phenotypic Correlation Coefficient, GCV = Genotypic Correlation Coefficient

σ^2_g = Genotypic variance = (Mean sum of squares due to genotypes – Error mean sum of squares) ÷ Replications

$$\sigma^2_p = \text{Phenotypic variance} = \sigma^2_g + \sigma^2_e$$

$$\sigma^2_e = \text{Environmental variance} = (\text{Error mean sum of squares}) \div \text{Replications}$$

$$\bar{x} = \text{General mean}$$

PCV and GCV were classified as suggested by Sivasubramanian and Menon (1973).

Less than 10% = Low

10-20% = Moderate

More than 20 % = High

Heritability in broad sense (h² (b)) was estimated as per the formulae suggested by Allard (1960).

$$h^2(b) = \frac{(\sigma^2_g)}{(\sigma^2_p)} \times 100$$

The heritability (h² (b)) was categorised as suggested by Johnson et al. (1955).

0-30% = Low

31-60% = Medium

61% and above = High

Genetic advance (GA) was estimated as per formula given by Allard (1960)

$$GA = K \times \sigma_p \times h^2(b) \text{ Where,}$$

K = Selection differential at 5 per cent selection intensity which accounts to a constant value 2.06

σ_p = Phenotypic standard deviation

Genetic advance over mean (GAM) was calculated using the following formula and was expressed in percentage.

$$GAM = \frac{(GA)}{\bar{x}} \times 100$$

The genetic advance as per cent over mean was categorized as suggested by Johnson et al. (1955).

Less than 10% = Low

10-20% = Moderate

More than 20 % = High

RESULT AND DISCUSSION

Analysis of variance (Table 5) revealed significant differences among the genotypes for all the traits indicating presence of significant variability in the genotypes which can be exploited through selection. The analysis of variance revealed that significant variability was present in the genotypes for all the characters under normal and limited moisture condition. This suggested that the material had adequate variability and response to selection may be excepted in the breeding programme for seed yield or any of its supporting characters. These results are in agreement with the findings of Shukla and Sharma (1978) in fenugreek, Dhayal and Bhargava (1997) in cumin, Patni (1983) in wheat, Sadaqat et al. (2003) in rape and Singh and Jat (2007a) in cumin in normal and moisture stress conditions. The values of all possible correlation coefficients among morphological characters at phenotypic and genotypic levels were calculated

under normal and limited moisture conditions and are presented in Table 1 and 2, respectively. In general the genotypic correlation coefficients were higher in magnitude than respective phenotypic correlation coefficients for most of the characters pairs. The direction of phenotypic and genotypic correlation coefficients was similar for most of the character combinations. The correlation between different characters under normal condition at phenotypic level, seed yield per plant had significant positive correlation with pods per plant (0.8461), seeds per pod (0.3336), branches per plant (0.3245) and pod length (0.2061). All other associations of seed yield per plant were found to be non-significant. The correlation among characters *inter se* showed that the association of days to 50 % flowering was found to be positive and significant with days to maturity (0.6609) and significant negative correlation with 1000-seed weight (-0.3679). The association of days to maturity was found to be negative and significantly correlated with 1000-seed weight (-0.3262) and significant positive correlation with plant height (0.2002). The association of plant height was found to be negative and significantly correlated with branches per plant (-0.3136). The association of branches per plant was found to be positive and significant with pods per plant (0.3740), seed yield per plant (0.3245) and seeds per pod (0.2142). The association of pods per plant was found to be positive and significant with seed yield per plant (0.8461), seeds per pod (0.2960) and pod length (0.2290). The association of seeds per pod was found to be positive and significant with pod length (0.7360) and seed yield per plant (0.3336). The association of pod length was found to be positive and significant with seed yield per plant (0.2061). The association of 1000-seed weight was found to be non-significant with all the characters.

Under limited moisture condition there was in general good correspondence between the correlation under normal and limited moisture condition (Table 1) Seed yield per plant had positive and significant correlation with pods per plant (0.8798), plant height (0.5440), seeds per pod (0.2771) and branches per plant (0.2550). Seed yield per plant had negative and non-significant correlation with 1000-seed weight.

The correlation among the characters *inter se* showed that association of days to 50% flowering was found to be positive and significant with days to maturity (0.6776) and plant height (0.2260). The association of days to maturity was positive and significant with plant height (0.2514). The association of plant height was found to be positive and significant with seed yield per plant (0.5440), pods per plant (0.5357) and seeds per pod (0.2220). The association of branches per plant was found to be positive and significant with pods per plant (0.3076) and seed yield per plant (0.2550), whereas,

the association with 1000-seed weight (-0.2739) was negative and significant. The association of pods per plant was found to be positive and significant with seed yield per plant (0.8797) and seeds per pod (0.2329). The association of seeds per pod was found to be positive and significant with pod length (0.5818) and seed yield per plant (0.2771). The association of pod length had non-significant correlation with all the characters. The association of 1000-seed weight had non-significant correlation with all the characters.

The association analysis revealed that seed yield per plant was significantly and positively correlated with branches per plant, pods per plant, seeds per pod and pod length in normal conditions. Whereas, it had positive and significant correlation with plant height, branches per plant, pods per plant and seeds per pod in limited moisture condition. For all the other characters the correlation estimates varied with the environmental conditions.

The association analysis revealed that seed yield per plant was significantly and positively correlated with branches per plant, pods per plant and seeds per pod in both the environment.

The genotypic correlation coefficients were generally stronger than the respective phenotypic correlation coefficients which indicated higher degree of association between two characters at genotypic level. Genetic correlation provides information about degree and direction of association between two or more than two variables. It may be result due to genetic causes, such as pleiotropic effect or linkage or it may also be due to environmental causes. The magnitude and direction of correlation coefficient varies with the genetic material being evaluated.

The knowledge of correlations is imperative as it facilitates quick assessment of the characters influencing the ultimate character, seed yield in the present case. Since, suitable test for significance of genotypic correlation coefficient is not available, major emphasis has therefore been put on phenotypic correlation coefficient. The seed yield per plant was found to be positively and significantly associated with branches per plant, pods per plant, seeds per pod and pod length. The association with pods per plant being the stronger in normal environment. In comparison, the correlation of seed yield per plant showed stronger correlation with most of the traits namely plant height, branches per plant, pods per plant and seeds per pod in stress environments. Reports of Sharma *et al.* (1990), Kailash Chandra (1992), Bajjiya and Pareek (1996) and Mahey *et al.* (2003) in fenugreek also support the above observations.

Path coefficient analysis helps in separating the direct effect of a component character on yield from indirect effect via other characters. The genotypic and phenotypic correlation coefficients of seed yield with its contributing characters were

partitioned into direct and indirect effect through path coefficient analysis. To assess the direct and indirect effect of various characters on seed yield, path coefficient analysis was carried out by taking seed yield as dependent variable and other yield components as independent variables. The results of path coefficient analysis, have been presented in Table 3 and 4 for each of the two environmental conditions.

Under normal condition, pods per plant showed highest direct effect at genotypic (1.4302) and phenotypic (0.8269) levels, respectively. The direct effect of pods per plant (1.4302), pods length (1.2984) and days to maturity (0.8864) was higher and positive, while high negative direct effect was observed for seeds per pod (-1.5586) followed by branches per plant (-0.2518), days to 50% flowering (-0.2413) at genotypic level. At phenotypic level, high positive direct effect was observed for pods per plant (0.8269), while moderate negative direct effect was observed for pod length (-0.1015). Days to 50% flowering showed high positive indirect effect via days to maturity (0.9928) at genotypic level. Days to maturity showed high negative indirect effect via seeds per pod (-0.5044) and days to 50% flowering (-0.2703) at genotypic level. Plant height showed high positive indirect effect via days to maturity (0.3121), whereas, high negative indirect effect via seeds per pod (-0.4098) at genotypic level. Branches per plant showed high positive indirect effect via pods per plant at genotypic and phenotypic level, 0.6168 and 0.3092, respectively, whereas, it showed high negative indirect effect via seeds per pod (-0.3418) at genotypic level. Pods per plant showed high positive indirect effect via pod length (0.4168), whereas, it showed high negative indirect effect via seeds per pod (-0.8553) at genotypic level. Seeds per pod showed high positive indirect effect via pod length (1.2550) and pods per plant (0.7849) at genotypic level. Pod length showed high positive indirect effect via pods per plant (0.4591), whereas, it showed high negative indirect effect via seeds per pod (-1.5065) at genotypic level. 1000-seed weight showed high negative indirect effect via days to maturity (-0.5843) at genotypic level.

On the basis of high and positive direct effects and correlation with seed yield it could be concluded that under normal condition direct selection for pods per plant may be effective for the improvement of seed yield per plant. Residual effect was of a high magnitude at phenotypic level (0.5191). The high residual effect was obtained due to weak correlation among the characters. These results suggest the need for diversification of germplasm collections incorporating more entries from geographically distant area.

Under limited moisture condition, the direct effect of pods per plant (1.0716 and 0.8134) were higher and positive at genotypic and phenotypic levels.

The direct effect of other characters were negligible. The direct effect of pods per plant (1.0716) followed by days to 50% flowering (0.1561) were higher and positive, whereas, moderate negative direct effect was observed for plant height (-0.1573) at genotypic level. High positive direct effect was observed for pods per plant (0.8134) at phenotypic level. Days to 50% flowering showed high positive indirect effect via pods per plant (0.3091) and days to maturity (0.1665) at genotypic level. Days to maturity showed high positive indirect effect via pods per plant (0.3230) and days to 50% flowering (0.2998) at genotypic level. Plant height showed high positive indirect effect via pods per plant (0.6670) at genotypic level. Branches per plant showed high positive indirect effect via pods per plant (0.3670) at genotypic level. Pods per plant showed negligible indirect effect at both genotypic and phenotypic levels. Seeds per pod showed high positive indirect effect via pods per plant (0.4022) at genotypic level. Pod length showed high positive indirect effect via pods per plant (0.3371) at genotypic level. 1000-seed weight showed negligible indirect effect at both genotypic and phenotypic level.

On the basis of high and positive direct effects and correlation coefficient with seed yield per plant, it could be concluded that under limited moisture condition direct selection for pods per plant may be effective for the improvement of seed yield per plant. The residual effect was of a high magnitude at genotypic and phenotypic levels, 0.2045 and 0.4593, respectively. The high residual effect was obtained due to weak correlation among the characters.

Path coefficient analysis indicated that direct selection for pods per plant in both the environments, was the important character for selection of high yielding genotype as this exerted high positive direct effect as well as showed high and positive correlation with seed yield.

Based on the present investigation it is suggested that in breeding programme major emphasis should be given to pods per plant in both the environmental conditions as it had positive correlation with seed yield per plant with high direct effect. On the other hand concerted efforts on evaluation of a larger number of genotypes are likely to identify genotypes worth exploitation in breeding programme to develop limited moisture stress tolerant varieties in fenugreek.

Information gained from correlation studies does not provide a clear picture of contribution of each component character to the final dependent character *i.e.* seed yield. At the same time as more variables are included in association studies, the direct association become complex and important. Under such situation path coefficient analysis is useful in partitioning direct and indirect causes of correlation and allow a detailed examination of

specific forces acting to produce a given correlation. Path analysis measures the relative importance of each, causal factor. Hence, this study provides a realistic basis for allocation of weightage to each attribute in deciding a suitable criterion for genetic improvement.

Though the path coefficient analysis was estimated at both phenotypic and genotypic levels, more emphasis was given to path coefficient analysis at phenotypic level. As such the direct effects at genotypic level were stronger than phenotypic level. In the present investigation path coefficient analysis was carried out by taking seed yield as dependent variable and all the yield components as independent variables. Path coefficient analysis over two environmental conditions indicated the variable contribution of different characters towards seed yield with change of environmental conditions. Change in the direction and magnitude of direct and indirect effects were noted between environments.

In normal condition all the traits which exhibited significant and positive correlations with seed yield per plant had high positive and direct effects on seed yield per plant indicating that the major portion of correlation is ascribed to direct effects. Among the traits, pods per plant had highest positive direct effect on seed yield per plant. This is followed by pod length at genotypic level. Seeds per pod exhibited high negative direct effect on seed yield per plant at genotypic level. The above findings are in conformity with Mehta *et al.* (1992), Sade *et al.* (1996), Lowanshi *et al.* (1998), Mahey *et al.* (2003) in fenugreek and Singh and Jat (2007b) in cumin.

In limited moisture condition also there was good correspondence between the correlations with seed yield per plant and direct effect. Similar to normal condition, the highest direct effect was exhibited by pods per plant. The later two traits i.e. pod length and 1000-seed weight had low correlation estimate with seed yield per plant in normal environment. Such results were earlier reported by Verma and Gulati (1981), Pathak *et al.* (1986) in wheat, Sadaqat *et al.* (2003) in rape, Singh *et al.* (2003) in barley, Singh and Jat (2007b) in cumin.

The extent of variability with respect to 9 characters in different genotypes measured in terms of mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) along with the amount of heritability (*h*), expected genetic advance and genetic advance as per cent of mean (GAM) are presented in Table 2.

The general mean of the characters was higher in normal environment in comparison to limited moisture condition for each of the trait as expected. Similarly the range was also wider in normal environment in comparison to limited moisture (C_2) for each of the trait. The mean days to 50% flowering was 57.87 and 52.89 days, respectively in normal and limited moisture condition. The mean days to

maturity was observed to be high in normal condition (142.54) and was low in limited moisture condition (133.82). The highest mean plant height was observed in normal condition (60.50 cm) and (36.83 cm) in limited moisture condition. Plant height had widest range in limited moisture condition and lowest in normal condition. Mean branches per plant was observed to be high in normal condition (3.59) and was low in limited moisture condition (3.28) although the values are nearly similar. The range was nearly similar in both the environments. The mean number of pod per plant was 27.67 in normal condition and 22.31 in limited moisture condition. The range was narrow in limited moisture condition. The mean seeds per pod was higher in normal condition (16.70) in comparison to limited moisture condition (16.43). The range was nearly similarly in both the environments. The mean pod length was high in limited moisture condition (8.43 cm) and was low in normal condition (8.37 cm). The mean 1000-seed weight was high in normal condition (12.07 g) and was low in limited moisture condition (11.39 g). The mean seed yield per plant was high in normal condition (5.03 g) and was low in limited moisture condition (3.66 g).

Change in the means of character in limited moisture condition in comparison to normal condition were noted. Mean values were higher in normal condition in comparison to limited moisture condition, as expected, for the characters *viz.*, days to 50% flowering, day to maturity, plant height, pods per plant and seed yield per plant. Pod length had higher mean value in limited moisture condition in comparison to normal condition. This indicated clearly the adverse effect of moisture stress on the character expression by the genotypes. Similar findings was reported by Jat *et al.* (1990) in wheat under moisture stress condition on seed yield and other traits. The mean values of characters branches per plant, seeds per pod and 1000-seed weight varied little across environmental conditions.

In order to get unit free estimates of variation, coefficients of variation, namely. PCV and GCV were estimated for all the characters (Table 3 and 4, respectively). The phenotypic variances were higher than the respective genotypic variances due to the effect of non-heritable components of variance. The phenotypic variances ranged from 1.26% (days to maturity) to 19.52% (seed yield per plant) in normal condition and was 1.39% (days to maturity) to 22.00% (seed yield per plant) in limited moisture condition. In normal condition highest PCV was recorded for seed yield per plant (19.52%) followed by pods per plant (15.06%) and moderate value of PCV was recorded for branches per plant (12.49%), plant height (9.65%) and 1000-seed weight (7.08%). Low PCV values were recorded for seeds per pod (4.54%), pods length (4.13), days to 50% flowering (2.03) and days to maturity (1.26%). In limited moisture condition, highest PCV value was recorded

for seed yield per plant (22.00%) followed by branches per plant (20.42%) and pods per plant (15.09 %), whereas, moderate values of PCV was recorded for plant height (13.82%) and 1000-seed weight (7.37%) and low PCV values were recorded for seeds per pod (6.46%), pod length (6.34), days to 50% flowering (2.43%) and days to maturity (1.39%).

In normal condition, the highest GCV value was recorded for seed yield per plant (18.00%) followed by pods per plant (14.17%), moderate value of GCV was recorded for branches per plant (10.86%) and plant height (9.46%), while lower values of GCV were recorded for 1000-seed weight (5.46%), pod length (2.83%), seeds per pod (2.51%), days to 50% flowering (0.95%) and days to maturity (0.74%). In limited moisture condition, the highest GCV was recorded for seeds yield per plant (20.56%) followed by branches per plant (19.42%), moderate values of GCV were recorded for pods per plant (13.48%) and plant height (13.11%). Whereas, low GCV values were observed for 1000-seed weight (5.10%), seeds per pod (3.82%), pod length (3.16%), days to 50% flowering (1.07%) and days to maturity (0.53%).

Comparison among the characters indicated that GCV and PCV values varied little across environmental conditions for days to 50% flowering, days to maturity, pods per plant, 1000-seed weight and seed yield per plant. For plant height, branches per plant, seeds per pod and pod length, the GCV and PCV values were higher in limited moisture condition in comparison to normal condition.

The phenotypic coefficients of variation were in general higher than the genotypic coefficient of variation for all the characters, which indicated effect of environments on the character expression.

It is a common knowledge that the change in mean is associated with higher variation for most of the traits in stress conditions (Paroda and Chopra, 1986). The estimates of coefficients of variations were in general higher in stress environment than in normal. In both the environments high estimates of variation were observed for traits, plant height, branches per plant, pods per plant and seed yield per plant, thus selection may be more effective for these characters because the response to selection is directly proportional to the variability present in the experimental material. Similar findings were reported by Singh and Jat (2007a) in cumin under normal and stress conditions. Low estimates of variation was observed for days to 50% flowering, days to maturity, seeds per pod and pod length in both the conditions, which indicated that selection might not be effective for these characters. Similar results were reported by Kohli et al. (1988), Reddy and Reddy (1991), Kailash Chandra *et al.* (2000) in fenugreek and Singh and Jat (2007a) in cumin.

Comparison among the characters indicated that GCV and PCV values varied little across environments for pods per plant and seed yield per

plant. For characters plant height, branches per plant and seeds per pod the GCV and PCV values were of higher magnitude in limited moisture condition.

Heritability in broad sense was estimated for all the characters (Table 6 and 7) in each of the environments. Heritability estimates varied from one environment to the other. In normal condition, high (> 60%) heritability estimates were recorded for plant height (95.99%) followed by pods per plant (88.60%), seed yield per plant (85.04) and branches per plant (75.54%) and moderate (40-60%), heritability was recorded for 1000-seed weight (59.32%) and pods length (46.96%), whereas low heritability (< 40%) estimates were recorded for days to 50% flowering (21.87%), seeds per pod (30.51%) and days to maturity (34.14%).

In limited moisture condition, high (>60%) heritability estimates were recorded for branches per plant (90.50%) followed by plant height (90.07%), seed yield per plant (87.34%) and pods per plant (79.76%), whereas moderate (40-60%) estimates of heritability were recorded for 1000-seed weight (47.75%). Whereas, low estimates (<40%) were recorded for seeds per pod (34.89%), pod length (24.81%), days to 50% flowering (19.22%) and days to maturity (14.35%).

High estimates of heritability were recorded for plant height, pods per plant, seed yield per plant and branches per plant in both the environment, moderate estimates for 1000-seed weight and low estimates were recorded for days to 50% flowering, seeds per pod and days to maturity in both the environments.

Comparison among the characters indicated that, the heritability values varied across the environmental conditions. For days to 50% flowering, days to maturity, plant height, pods per plant, pod length and 1000-seed weight, the heritability value was higher in normal condition in comparison to limited moisture condition. The heritability values were higher in limited moisture condition for traits *viz.*, branches per plant, seeds per pod and seed yield per plant in comparison to normal condition.

Expected genetic advance as percentage of mean was calculated for all the characters (Table 3 and 4) in each of the environment. In normal condition, genetic advance as percentage of mean ranged from 0.89% (days to maturity) to 34.19% (seed yield per plant). Higher values of genetic advance as percentage of mean were recorded for seed yield per plant (34.97%) followed by pods per plant (27.48%), while, moderate values of genetic advance as percentage of mean were recorded for branches per plant (19.44%) and plant height (19.09). Low values for genetic advance as percentage of mean were recorded for 1000-seed weight (8.66%), pod length (4.00%), seeds per pod (2.85%), days to 50% flowering (0.91%) and days to maturity (0.89%).

In limited moisture condition, genetic advance as percentage of mean ranged from 0.41% (days to maturity) to 39.59% (seed yield per plant). Higher

values of genetic advance as percentage of mean was recorded for seed yield per plant (39.59%) followed by branches per plant (36.06%), while moderate values of genetic advance as percentage of mean were recorded for plant height (25.63%) and pods per plant (24.79%). Low values for genetic advance as percentage of mean were recorded for 1000-seed weight (7.25%), seeds per pod (4.64%), pod length (3.24%), days to 50% flowering (0.96%) and days to maturity (0.41%).

Comparison among the characters indicated that, value of genetic advance as percentage of mean varied little across environmental conditions for days to 50% flowering, day to maturity, seeds per pod, pod length and 1000-seed weight. For characters like plant height, branches per plant and seed yield per plant the genetic advance as percentage of mean values were higher in limited moisture condition in comparison to normal condition. For pods per plant the genetic advance as percentage of mean were higher in normal condition in comparison to limited moisture condition.

The heritability estimates along with the genetic advance are more meaningful. Estimates of heritability serves as an useful guide to the breeder. The breeder is able to appreciate the proportion of variation that is due to the genotype (broad sense heritability) or additive (narrow sense heritability) effects *i.e.* the heritable portion of variation of the first case, and the portion of genotypic variation that is fixable in pure lines in the later case. If heritability of a character is high ($> 60\%$), selection for such a characters should be fairly easy. This is because there would be close correspondence between genotypic and phenotypic variation due to a relatively smaller contribution of environment to the phenotype, but for a character with a low heritability ($< 40\%$), selection may be considerably difficult or virtually impractical due to masking effect of environment on the genotypic effect.

In present investigation broad sense heritability was observed to be high for plant height followed by pods per plant, seed yield per plant and branches per plant in normal condition and for most of the characters except days to 50% flowering, days to maturity, seeds per pod, pod length and 1000-seed weight in limited moisture condition, which is agreement with earlier reports of high heritability for plant height, 1000-seed weight in normal condition and for branches per plant, 1000-seed weight and seed yield per plant characters in limited moisture condition in cumin by Singh and Jat (2007a) and for pods per plant and branches per plant in fenugreek by Mehta *et al.* (1992); for plant height by Kohli *et al.* (1988), Kailash Chandra *et al.* (2000); for 1000-seed weight by Berwal *et al.* (1996) and Singh (2000) and for seed yield per plant by Sharma *et al.* (1990), Meena (1994) and Singh (2000) and for most of the characters except pod length by Paramjit Singh and Amardeep Kaur (2007) in fenugreek. While the

estimates of heritability changed very little between the environments for traits - plant height, and seed yield per plant. The change was considerable for days to maturity, pod length and 1000-seed weight. The estimates were higher in the normal environment.

Heritability estimates alone do not provide information on the amount of genetic progress that would result from the selection of the best genotype. Johnson *et al.* (1955) has pointed out that heritability estimates along with genetic advance were more useful than heritability estimates alone in predicting the response to selection. Therefore, genetic advance as percentage of mean was calculated in order to determine the relative merits of different characters that can be further utilized in the selection programme.

In normal condition high magnitude of genetic advance as percentage of mean was obtained for pods per plant and seed yield per plant which is in agreement with earlier reports of Reddy and Reddy (1991) and Singh (2000) for seed yield per plant and pods per plant. Moderate genetic advance as percentage of mean was observed for plant height and branches per plant is in agreement with the reports of moderate genetic advance for plant height by Singh (2000). Low magnitude of genetic advance as percentage of was observed for days to 50% flowering, days to maturity, seeds per pod, pod length and 1000-seed weight which is in agreement with the earlier reports of low genetic advance for 1000-seed weight by Kohli *et al.* (1988), for pod length by Shukla (1978), Kohli *et al.* (1988) and Singh (2000); for number of seeds per pod by Kailash Chandra *et al.* (2000). However, in limited moisture condition characters branches per plant, seed yield per plant and plant height had high heritability along with high genetic advance as percentage of mean which indicated that these characters may be under the control of additive gene action and selection of these character may be effective. The characters pods per plant had high heritability with moderate genetic advance as percentage of mean. Comparison of the genetic advance estimates between the environments indicated that minimum change in the estimates were observed for seed yield per plant. While the changes was considerable for trait - branches per plant and plant height, while in branches per plant, seed yield per plant and plant height, the estimates increased in stress in comparison to normal environment. The estimates was lower in pods per plant in stress in comparison to normal environment. Days to 50% flowering, seeds per pod and 1000-seed weight had high heritability and low genetic advance as percentage of mean. Days to 50% flowering and low heritability with low genetic advance as percentage of mean. These finding are in agreement with earlier report of Singh and Jat (2007a) in cumin.

Table 1. Genotypic and phenotypic correlation coefficients between different characters in fenugreek under normal condition

Characters		Days maturity	to	Plant height (cm)	Branches per plant	Pods plant	per	Seeds pod	per	Pod (cm)	length	1000-seed weight (g)	Seed per plant (g)
Days to 50% flowering	G	1.1200		0.1658	0.1077	-0.1566		0.2471		-0.0803		-0.7682	-0.1108
	P	0.6609**		0.0921	0.0543	-0.0526		0.0035		-0.0298		-0.3679**	0.0021
Days to maturity	G			0.3521	0.1758	-0.0270		0.3236		0.0716		-0.6591	-0.0034
	P			0.2002*	0.1503	-0.0105		0.1452		0.0540		-0.3262**	0.0449
Plant height (cm)	G				-0.3708	-0.0675		0.2629		0.1688		-0.1941	-0.0473
	P				-0.3136**	-0.0589		0.1382		0.1193		-0.1536	-0.0362
Branches per plant	G					0.4313		0.2193		0.1425		0.0172	0.3772
	P					0.3740**		0.2142*		0.1581		0.0240	0.3245**
Pods per plant	G							0.5488		0.3210		0.1510	0.9243
	P							0.2960**		0.2290*		0.0981	0.8461**
Seeds per pod	G									0.9666		0.0296	0.6314
	P									0.7360**		0.0260	0.3336**
Pod length (cm)	G											0.1462	0.3013
	P											0.0372	0.2061*
1000-seed weight (g)	G											0.1129	
	P											0.0535	

* and ** refers to significant at P = 0.05 and P = 0.01, respectively

Table 2. Genotypic and phenotypic correlation coefficients between different characters in fenugreek under limited moisture condition

Characters		Days maturity	to	Plant height (cm)	Branches per plant	Pods plant	per	Seeds pod	per	Pod (cm)	length	1000-seed weight (g)	Seed per plant (g)
Days to 50% flowering	G	1.9208		0.5700	0.2431	0.2884		0.5590		-0.0645		-0.2418	0.4223
	P	0.6776**		0.2260*	0.1596	0.0964		0.1211		0.0713		-0.1384	0.1483
Days to maturity	G			0.6888	0.2020	0.3014		0.8316		-0.0144		-0.3676	0.4493
	P			0.2514**	0.1025	0.1221		0.1016		0.0780		-0.0741	0.1621
Plant height (cm)	G				0.1857	0.6224		0.4228		0.3095		-0.1337	0.5897
	P				0.1709	0.5357**		0.2220*		0.1574		-0.0706	0.5440**
Branches per plant	G					0.3425		-0.2381		0.0608		-0.4328	0.2837
	P					0.3076**		-0.1220		0.0654		-0.2739**	0.2550**
Pods per plant	G							0.3753		0.3146		-0.0205	0.9645
	P							0.2329**		0.1099		-0.0524	0.8798**
Seeds per pod	G									0.8746		0.0274	0.4410
	P									0.5818**		-0.0327	0.2771**

Pod length (cm)	G							-0.1528	0.2029
	P							0.0393	0.1242
1000-seed weight (g)	G								-0.0006
	P								-0.0423

* and ** refers to significant at P = 0.05 and P = 0.01, respectively

Table 3. Genotypic and phenotypic path coefficients between different characters in fenugreek under normal condition

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Branches per plant	Pods per plant	Seeds per pod	Pod length (cm)	1000-seed weight (g)	Correlation with seed yield per plant (g)
Days to 50% flowering	G	-0.2413	0.9928	-0.0164	-0.0271	-0.2240	-0.3851	-0.1043	-0.1054	-0.1108
	P	0.0281	0.0102	-0.0009	-0.0006	-0.0435	0.0006	0.0030	0.0051	0.0021
Days to maturity	G	-0.2703	0.8864	-0.0349	-0.0443	-0.0386	-0.5044	0.0930	-0.0905	-0.0034
	P	0.0186	0.0154	-0.0019	-0.0016	-0.0087	0.0240	-0.0055	0.0045	0.0449
Plant height (cm)	G	-0.0400	0.3121	-0.0990	0.0934	-0.0965	-0.4098	0.2192	-0.0266	-0.0473
	P	0.0026	0.0031	-0.0093	0.0033	-0.0487	0.0228	-0.0121	0.0021	-0.0362
Branches per plant	G	-0.0260	0.1558	0.0367	-0.2518	0.6168	-0.3418	0.1850	0.0024	0.3772
	P	0.0015	0.0023	0.0029	-0.0105	0.3092	0.0354	-0.0160	-0.0003	0.3245**
Pods per plant	G	0.0378	-0.0239	0.0067	-0.1086	1.4302	-0.8553	0.4168	0.0207	0.9243
	P	-0.0015	-0.0002	0.0005	-0.0039	0.8269	0.0489	-0.0232	-0.0014	0.8461**
Seeds per pod	G	-0.0596	0.2869	-0.0260	-0.0552	0.7849	-1.5586	1.2550	0.0041	0.6314
	P	0.0003	0.0022	-0.0013	-0.0023	0.2447	0.1651	-0.0747	-0.0004	0.3336**
Pod length (cm)	G	0.0194	0.0635	-0.0167	-0.0359	0.4591	-1.5065	1.2984	0.0201	0.3013
	P	-0.0008	0.0008	-0.0011	-0.0017	0.1893	0.1215	-0.1015	-0.0005	0.2061*
1000-seed weight (g)	G	0.1854	-0.5843	0.0192	-0.0043	0.2160	-0.0461	0.1898	0.1373	0.1129
	P	-0.0103	-0.0050	0.0014	-0.0003	0.0811	0.0043	-0.0038	-0.0140	0.0535

Residual effect : Genotypic = 0.5673

Phenotypic = 0.5191 * and ** refers to significant at P = 0.05 and P = 0.01, respectively

Table 4. Genotypic and phenotypic path coefficients between different characters in fenugreek under limited moisture condition

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Branches per plant	Pods per plant	Seeds per pod	Pod length (cm)	1000-seed weight (g)	Correlation with seed yield per plant (g)
Days to 50% flowering	G	0.1561	0.1665	-0.0897	-0.0330	0.3091	-0.0772	-0.0038	-0.0058	0.4223
	P	-0.0638	0.1117	0.0155	0.0003	0.0784	0.0101	-0.0024	-0.0015	0.1483
Days to maturity	G	0.2998	0.0867	-0.1083	-0.0274	0.3230	-0.1148	-0.0008	-0.0088	0.4493
	P	-0.0432	0.1649	0.0172	0.0002	0.0180	0.0085	-0.0026	-0.0008	0.1621

Plant height (cm)	G	0.0890	0.0597	-0.1573	-0.0252	0.6670	-0.0584	0.0181	-0.0032	0.5897
	P	-0.0144	0.0415	0.0684	0.0003	0.4358	0.0185	-0.0053	-0.0008	0.5440**
Branches per plant	G	0.0379	0.0175	-0.0292	-0.1356	0.3670	0.0329	0.0036	-0.0104	0.2837
	P	-0.0102	0.0169	0.0117	0.0018	0.2502	-0.0102	-0.0022	-0.0031	0.2550**
Pods per plant	G	0.0450	0.0261	-0.0979	-0.0465	1.0716	-0.0518	0.0184	-0.0005	0.9645
	P	-0.0062	0.0201	0.0366	0.0006	0.8134	0.0194	-0.0037	-0.0006	0.8798**
Seeds per pod	G	0.0872	0.0721	-0.0665	0.0323	0.4022	-0.1380	0.0511	0.0007	0.4410
	P	-0.0077	0.0168	0.0152	-0.0002	0.1894	0.0834	-0.0194	-0.0004	0.2771**
Pod length (cm)	G	-0.0101	-0.0013	-0.0487	-0.0083	0.3371	-0.1207	0.0584	-0.0037	0.2029
	P	-0.0046	0.0129	0.0108	0.0001	0.0894	0.0485	-0.0334	0.0004	0.1242
1000-seed weight (g)	G	-0.0377	-0.0319	0.0210	0.0587	-0.0220	-0.0038	-0.0089	0.0239	-0.0006
	P	0.0088	-0.0122	-0.0048	-0.0005	-0.0426	-0.0027	-0.0013	0.0111	-0.0442

Residual effect : Genotypic = 0.2045 Phenotypic = 0.4593 * and ** refers to significant at P = 0.05 and P = 0.01, respectively

Table 5. Pooled ANOVA for different characters of fenugreek genotypes evaluated under normal (C₁) and limited moisture (C₂) conditions

S. No.	Characters	Source of variation with d.f.				
		E 1	R 4	G 59	G×E 59	Error 236
1.	Days to 50% flowering	2225.06**	2.38	3.66**	0.61	1.21
2.	Days to maturity	6838.23**	4.87	8.66**	1.26	2.55
3.	Plant height (cm)	50434.66**	2.77	119.96**	52.19**	1.97
4.	Branches per plant	8.71**	0.04	0.87**	0.89**	0.05
5.	Pods per plant	2578.70**	3.48	51.33**	26.17**	2.14
6.	Seeds per pod	6.53**	0.89	1.69**	1.14**	0.57
7.	Pod length (cm)	0.32	0.22	0.39**	0.27**	0.14
8.	1000-seed weight (g)	41.47**	0.43	2.64**	0.33	0.33
9.	Seed yield per plant (g)	170.19**	0.18	2.99**	1.40**	0.11

* and ** refers to significant at P = 0.05 and P = 0.01, respectively

Table 6. Mean, range, estimate of variances, coefficients of variation, heritability (broad sense) and genetic advance for yield and other attributes (normal condition)

S.	Characters	Mean	Range	Estimates of variance			Coefficients of variation		Heritabilit	GA as	
				$\sigma^2 e$	$\sigma^2 g$	$\sigma^2 p$	Environment	Genotypic			
No.				$\sigma^2 e$	$\sigma^2 g$	$\sigma^2 p$	Environment	Genotypic	Phenotypic	y % (bs)	%age of mean
1.	Days to 50% flowering	57.87	56.00-59.67	1.08	0.30	1.37	1.80	0.95	2.03	21.87	0.91
2.	Days to maturity	142.54	138.00-145.33	2.13	1.11	3.24	1.02	0.74	1.26	34.14	0.89

3.	Plant height (cm)	60.50	46.10-71.07	1.37	32.75	34.12	1.93	9.46	9.65	95.99	19.09
4.	Branches per plant	3.59	2.97-4.37	0.05	0.15	0.20	6.22	10.86	12.49	75.54	19.44
5.	Pods per plant	27.67	20.70-37.63	1.98	15.37	17.35	5.08	14.17	15.06	88.60	27.48
6.	Seeds per pod	16.70	15.37-17.83	0.40	0.18	0.57	3.78	2.51	4.54	30.51	2.85
7.	Pod length (cm)	8.37	7.67-8.92	0.06	0.06	0.12	2.93	2.83	4.13	46.96	4.00
8.	1000-seed weight (g)	12.07	10.67-13.72	0.30	0.43	0.73	4.54	5.46	7.08	59.32	8.66
9.	Seed yield/plant (g)	5.03	2.70-6.93	0.14	0.82	0.96	7.44	18.00	19.52	85.04	34.19

Table 7. Mean, range, estimate of variances, coefficients of variation, heritability (broad sense) and genetic advance for yield and other attributes (limited moisture condition)

S. No.	Characters	Mean	Range	Estimates of variance			Coefficients of variation			Heritabilit	GA as %age of mean
				σ^2_e	σ^2_g	σ^2_p	Environment	Genotypic	Phenotypic		
1.	Days to 50% flowering	52.89	51.00-55.00	1.34	0.32	1.65	2.19	1.07	2.43	19.22	0.96
2.	Days to maturity	133.8	130.33-137.00	2.97	0.50	3.47	1.29	0.53	1.39	14.35	0.41
3.	Plant height (cm)	36.83	22.80-49.83	2.57	23.32	25.89	4.35	13.11	13.82	90.07	25.63
4.	Branches per plant	3.28	2.03-5.57	0.04	0.41	0.45	6.09	19.42	20.42	90.50	38.06
5.	Pods per plant	22.31	14.17-29.23	2.29	9.04	11.33	6.78	13.48	15.09	79.76	24.79
6.	Seeds per pod	16.43	15.00-18.23	0.73	0.39	1.13	5.20	3.82	6.46	34.89	4.64
7.	Pod length (cm)	8.43	7.83-8.98	0.22	0.07	0.29	5.56	3.16	6.34	24.81	3.24
8.	1000-seed weight (g)	11.39	9.46-12.62	0.37	0.34	0.71	5.34	5.10	7.37	47.75	7.25
9.	Seed yield/ plant (g)	3.66	1.70-5.62	0.08	0.57	0.65	7.73	20.56	22.00	87.34	39.59

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