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Stability Analysis in Fenugreek (*Trigonella foenum-graecum* L.)

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A set of 42 diverse genotypes of fenugreek (*Trigonella foenum-graecum* L.) was studied for stability analysis for grain yield and its components over four environments. The pooled analysis of variance revealed that the mean square due to genotypes were significant for all the traits studied except branches per plant. Environment wise analysis of variance was significant for all the traits in all the environments. Genotype x environment interaction was significant for all the characters except branches per plant and pod length. Environment + (variety x environment) component was significant for most of the traits. Mean seed yield was linearly influenced by the environment it was lowest in the most unfavorable environment. The test weight and branches per plant was least affected by environments. Considering all the characters the genotypes UM-36, RMt-303, UM-4 and UM-30 were found stable for seed yield.

Key words: Fenugreek, G X E interactions, Stability parameters

Fenugreek (*Trigonella foenum-graecum* L.) (2n = 16) is a self -pollinated crop. (Frayer, 1930). Popularly known as "*methi*" it is an important condiment crop largely grown in northern India during *rabi* season. It is grown both for grain as well as for fodder purpose. Fenugreek occupies an area 102432 ha with an annual production and productivity of 90409 tonnes and 882.61 kg/ha, respectively (Anonymous, 2010 and Sreekumar, 2010). Seeds are used as carminative and an ingredient of several Ayurvedic medicines, mainly those prescribed for promoting appetite, correcting digestive disorders and for relieving the pain of joints particularly in old age of life. Its tender leaves are consumed as leafy vegetable, chopped leaves are mixed in flour to prepare "Paratha". In addition to this it serves as a soil renovating crop. The leaves and shoots are quite rich in protein, minerals and vitamins A and C. Rao and Sharma (1987) reported that fenugreek seeds contain 25.5% protein, 7.9% fat, 20% mucilaginous matter and 4.8% saponins. In recent years the importance of fenugreek has further increased due to the presence of a steroid called "Diosgenin". Diosgenin is used in the synthesis of sex hormones and oral contraceptives.

Despite the economic importance of fenugreek, it is still cultivated on marginal lands with poor and limited irrigation facility because of which, the productivity is still low. Further, lack of availability of seed of improved and stable variety results in cultivation of local genotypes, which are susceptible to abiotic stresses. Since, the knowledge on the stability of yield of these genotypes would be advantageous to judge their real performance in wider environmental conditions. In the present study was carried out to investigate the genotypes X environment interaction for yield and its contributing traits under different environments to identify the tolerant genotypes with high yield and better stability in the target environments.

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Materials and Methods

The present study comprised 42 elite genotypes of fenugreek (Table 1) of diverse origin including local check obtained from the germplasm collection of AICRP on Spices located at S.K.N. College of Agriculture, Jobner. The above experimental materials were evaluated in RBD with 3 replications during *rabi* season 2010-11 in four artificially created environments namely, environment -I [Normal irrigation, normal date of sowing (29 October)], environment-II [limited irrigation (half of the normal irrigation, normal date of sowing), environment-III [Normal irrigation, late date of sowing (after 10 days of normal date of sowing)] and environment-IV [limited irrigation (half of the normal irrigation), late date of sowing(after 10 days of normal date of sowing]. In each environment and replication, genotypes were sown in a plot size 3.0 x 0.3 m_2 consisting of one row. The row to row and plant to plant distance was kept 30 cm and 10 cm, respectively. The field observations were recorded randomly selected and tagged five plants before flowering from each plot replication/environment. The data were recorded on the attributes *viz;* 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 five plants (g). Data for days to 50 per cent flowering were recorded on plot basis.

The statistical analyses of variance were carried out for each environment (Panse and Sukhatme, 1978) apart from pooled analysis of variance (Singh and Choudhary, 1979). The stability analysis was done with the model proposed by Eberhart and Russell (1966).

Results and Discussion

Analysis of Variance

Environment-wise analysis of variance revealed that significant differences existed among genotypes in each environment for all the characters. The pooled analysis also revealed significant differences among genotypes for all the traits except branches per plant, indicating that real differences existed among the genotypes. The environments also differ significantly for all the traits except branches per plant (Table 2). This indicated that the environments caused wide differences on the performance of genotypes.Further Genotype x environment interactions was significant for all the traits except branches per plant and pod length. This indicated the differential response of genotypes in the expression of the characters to varying environments.

Table 1. List of genotypes

S.No.	Genotype	Source/Origin
1.	UM-1	Ramganj Mandi Kota
2.	UM-2	Ramganj Mandi Kota
3.	UM-3	Kota
4.	UM-4	Kota
5.	UM-5	Kota
6.	UM-6	Raypur
7.	UM-7	Pirawa Jhalawar
8.	UM-8	Eklera, Jhalawar
9.	UM-9	Gelani, Jhalawar
10.	UM-10	Patan, Jhalawar
11.	UM-11	Asnawar Jhalawar
12.	UM-12	Bhawani Mandi, Kota
13.	UM-13	Bhawani Mandi, Kota
14.	UM-14	Bhawani Mandi, Kota
15.	UM-15	Khanpur
16.	UM-16	Mundala
17.	UM-17	Rawal, Jhalawar
18.	UM-18	Raipur, Jhalawar
19.	UM-19	Garwar, Jhalawar
20.	UM-20	Rawal, Jhalawar
21.	UM-21	Jahirabad
22.	UM-22	M.P. Type
23.	UM-23	Nandyal
24.	UM-24	Guntkal
25.	UM-25	Anantpur
26.	UM-26	Valpur
27.	UM-27	Oonja
28.	UM-28	Guntur
29.	UM-29	Nellore
30.	UM-30	Ongole
31.	UM-31	Seksar, Nagaur
32.	UM-32	Alaniyavas, Nagaur
33.	UM-33	Jamsar Nagaur
34.	UM-34	Nagaur
35.	UM-35	Seksar, Nagaur
36.	UM-36	Coimbatore, T.N.
37.	RMt-1	Nagaur
38.	RMt-143	Jodhpur
39.	RMt-303	Mutant of RMt-1
40.	RMt-305	Mutant of RMt-1
41.	RMt-351	Mutant of RMt-1
42.	LOCAL	Jobner

Non significant G X E interactions was observed for branches per plant and pod length which indicated that these characters are least influenced by the environments. These finding are in concurrence with earlier report by Tosniwal (1984) in fenugreek. The variance due to environment (linear) was significant and was linear. Some similar studies inferred that when the non-linear component of GXE was predominant, the mean performance of the varieties would not be predicted over environments. A linear environmental variance signifies unit change in environment index for each unit change in the environmental conditions. The G X E (linear) variance was significant for days to 50% flowering and seed yield. It indicated that genotypes had divergent linear response to the environmental changes. The G x E (linear) was not significant for remaining characters indicating that variation in the performance of genotypes was unpredictable. The environment + (variety x environment) component was significant for most of the characters excepting for branches per plant, seeds per plant and test weight. Further, pooled deviations were significant for all the characters which suggested that performance of different genotypes fluctuated significantly from their respective linear path of response to environments. In other words, the unpredictable environments formed the major portion of the G X E interactions, indicating non-predictable performance of genotypes across to environments (Table 2). These finding are supported by Jatasra and Paroda (1980), Solanki and Choudhary (1996), Pan *et al*. (2002), kole (2005), Pillai *et al*. (2010), Choudhary (2010) and Tomar *et al*. (2010) for different characters in various crops. It may be concluded that for seed yield both linear as well as non-linear components were highly significant indicating that the both predictable and unpredictable components contributed significantly, towards the differences in stability among different genotypes.

Stability parameters

The seed yield as well as other quality traits varied under variable environments. Therefore, it is necessary to breed the varieties suitable and stable for the different environments and can be used as donor parents in future breeding programmes. The genotypes identified for different traits are presented

Table 2. Pooled regression analysis for different yield contributing traits in fenugreek.

Source	d.f.	Days to 50% flowering	Plant height (cm)	Branches per plant	Pods per plant	Pod length (cm)	Seeds per pod	Test weight (g)	Seed yield (g)
Genotypes	41	623.199**	341.933**	0.576	60.388**	2.232**	6.165**	55.768**	204.484**
Environment	3	696.254**	10924.51**	1.243	3036.739**	48.081**	30.361**	75.518**	8268.394**
Env. X Geno.	123	23.465**	56.577**	0.17	38.42**	0.852	4.393**	15.419**	87.402**
Env. (Linear)	1	694.986**	11113.779**	1.250**	3041.904**	48.259**	30.788**	75.726**	8257.358**
Gen. * Env. (Linear)	41	20.423**	10.955	0.065	15.678	0.272	1.637	4.287	42.776**
Env. + (Gen. * Env.)	126	13.201**	105.022**	0.065	36.661**	0.661**	1.661	5.616	94.134**
Pooled deviation	84	1.560**	19.877**	0.051**	11.126**	0.284**	1.326**	5.429**	22.020**
Pooled Error	328	0.363	1.150	0.0314	0.664	0.135	0.311	0.101	0.918

*, ** = Significant at 5% and 1% levels, respectively

in Table 3. Earlier Finlay and Wilkinson (1963) reported that stable genotypes are those genotypes that have the higher mean, unit regression coefficient (b = 1) and non significant deviation from regression ($S_{2}di$=0). Accordingly, an absolute phenotypic stability would be expressed by genotype having zero regression coefficient (b = 0). It means that a stable genotype performs relatively better under adverse

Table 3. Stable genotypes and their estimates of stability parameters for different morphological traits.

Stable genotype	Mean	bi	$S_{2}di$
Days to 50% flowering			
UM-6	55.08	1.03	-0.20
UM-7	55.33	0.99	-0.09
UM-9	56.91	1.11	-0.26
Plant height (cm)			
UM-14	82.33	1.05	1.46
RMt-303	83.01	1.06	1.46
UM-36	83.40	1.08	-0.38
Branches per plant			
UM-22	2.15	0.92	-0.029
UM-23	2.23	1.12	-0.03
UM-24	2.46	0.93	-0.00
Pods per plant			
UM-22	30.18	1.02	1.24
UM-24	27.97	1.27	-0.20
UM-21	26.90	0.89	-0.54
Pod length (cm)			
UM-23	10.34	0.91	-0.19
UM-24	10.45	1.12	-0.06
UM-29	9.88	1.04	0.17
Seeds per pod			
UM-14	16.33	0.88	0.42
UM-18	17.41	1.16	0.52
UM-21	16.96	0.87	1.46
Test weight (g)			
UM-4	15.06	-1.40	3.86
UM-10	14.63	-1.24	2.25
UM-26	13.62	1.22	7.65
Seed yield (g)			
UM-4	27.34	1.08	2.41
RMt-303	27.61	1.03	32.47
UM-36	30.64	1.06	46.55

conditions and does relatively poor under favourable environments. The area and conditions where agriculture is not advanced breeder may prefer to have such stable genotype, but under advance agriculture conditions, breeder would like to have genotypes, that do above average in all environments. Obviously, high stability may not permit exploitation of better environments. Since the desirability of a genotype is also dependent upon it performance i.e. the mean value of the character besides stability, the varieties were classified in conjunction with the mean performance of the genotype over the environments for desirability. Fenugreek is cultivated in dry sandy soil of Rajasthan and required more irrigations. A genotype which performs well under limited number of irrigations is desirable.

A perusal of results indicated that the genotypes UM-6, UM-7 and UM-9 were found stable for days to 50% flowering as these genotypes had earliness, unit regression coefficient (bi=1) and non significant deviation from regression ($S_{2}di$=0) (Table 3). Earliness is desirable character in the area where water stress, edaphic or atmospheric adversities prevails during growing season, particularly in later part, so that the genotype may escape the adversities and mature before such stresses occurs.

Fenugreek plant height is reported to be positively associated with seed yield (Shukla and Sharma, 1978). In present study of most of these genotypes UM-36 have significant $S_{2}d$ values and therefore unstable for plant height are most stable and desirable genotypes. For branches per plant it may be concluded that UM-24, UM-23 and UM-22 are the most stable genotypes for this character. Most of the genotypes exhibited significant deviation from regression indicating their unstable performance for pods per plant . However, based on mean and regression coefficient, UM-22, UM-24 and UM-21 are the most stable among all the genotypes. For pod length most of the genotypes had non-significant $S_{2}d$ estimates. Among all the genotypes UM-23, UM-24 and UM -29 was found stable and most desirable for pod length. Seeds per pod is also an important yield contributing traits. Thus, those genotypes having more seeds per pod are expected to be high yielders. In the present study, the mean seeds per pod were highest in UM-33 in comparison to other genotypes. Besides, UM-14, UM-18 and UM-21 had high mean and b close to unity, thus are stable genotypes.

The $S_{2}d$ estimates of most of the genotypes for test weight were significantly deviated from zero but $S_{2}d$ estimates of UM-11 and UM-21 was non-significant, whereas UM-4, UM-10 and UM-26 were found stable as these genotypes had high mean and regression coefficient near to unity. The S_2d estimates for seed yield were non-significant in the genotypes except UM-2 and UM-15, UM-36, RMt-303 and UM-4 are considered to be most desirable genotypes because these genotypes had high mean than general mean and regression coefficient near about unity.

None of forty two varieties studied were found stable for all the characters, when compared on the basis of stability parameters namely, mean (x) and regression coefficient (b) and non significant deviations from regression (S_2 di=0). Yield is a complex trait and is controlled by a number of components. Most of the genotypes in present study were found stable and desirable for one or other yield component characters. Thus, it is obvious that breeding for stability of these components shall stabilize the seed yield. These finding are in concurrence with the earlier finding reported by Shukla and Sharma (1978), Singh and Raghuvanshi (1984), Kohli *et al*. (1988), Sharma *et al*. (1994), Sade *et al*. (1996), Berwal *et al*. (1996), Dash and Kole (2000), Chandra *et al*. (2000), Joshi *et al*.(2005) and Kole (2005) for different traits in various crops. In present investigation considering all the characters the genotypes UM-36, RMt-303, UM-4 and UM-30 were found relatively stable for seed yield. They may be used in hybridization programme to generate stable genotypes

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