Stability of fenugreek (Trigonella foenum-graecum L.) genotypes for terminal heat and water stress

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Received: 15-05-2014 Accepted: 15-07-2015 DOI: 10.18805/lr.v38i5.5934

ABSTRACT

Thirty genotypes of fenugreek (Trigonella foenum-graecum L.) were evaluated over four environments in randomized block design with 3 replications to estimate stability parameters of seed yield and its important component traits. The environments were created by changing the dates of sowing and irrigation levels. The genotypes interacted with the environments significantly indicating non linear response of genotypes to environments. Simple correlations between seed yield and other traits indicated that pods per plant and the test weight are the two important component traits. Stability analysis indicated difference in stability among the genotype for seed yield and the component traits. A positive correlation was noted between the regression coefficient and the mean seed yield of the genotypes, thus hypothesizing that higher yielding genotypes were better suited to better environments. The results of AMMI analysis corroborated with the results obtained from stability anlaysis, although AMMI analysis provided a better chance to delineate the genotypes and environments. Genotypes UM-137, UM-128, UM-322 and RMt-1 are found relatively stable for seed yield.

Key Words: Fenugreek, Correlation, Seed yield.

INTRODUCTION:

Genotype-environment interaction (GEI) is problematic for both the agronomist and breeder because phenotype of cultivars and breeding lines is affected by GEI, especially if the target environments are not similar. This interaction also reduces the association between phenotypes and genotypes, whereby selected genotypes in one environment may exhibit a poor performance in another environment (Romagosa and Fox, 1993). Therefore plant breeders aim to select genotypes with stable and high performing phenotypes via multi-environment trials (METs).

Between 1906 and 2005, the average surface temperature of earth increased progressively, by approximately 0.7°C, with the greater part of this increase occurring over the later 50 years (IPCC, 2007a, b). In addition, the frequency of extreme weather and climate events, in particular, heat waves, storms and floods due to heavy precipitations and extreme high sea levels increased over most land areas (Meehl et al., 2000; IPCC, 2007a, b). Possible adaptation strategies highlighted which are relevant to cool season grain legumes production include crop relocation, changes in sowing date, use of more stress tolerant genotypes, genetic adjustment of crops to increase their tolerance of stress, increased nutrient and plant protection inputs and intercropping with other crops to lower the risk of total crop failure under adverse conditions. Genetic adjustment of cool season grain legume crops should also include consideration of the rhizobial symbiosis (Andrews et al., 2010). It is important to note that one of the ways the climate change can be mitigated is the change in sowing date.

Fenugreek is an important spice crop of India and particularly for the state of Rajasthan. It is estimated that 80% of the area under fenugreek cultivation in India is localized within Rajasthan (Sastry et al., 2013). Fenugreek is a cool season crop, requiring frequent light irrigations during the cropping season. In general, like most of the rabi crops, the sowing of fenugreek starts during the month of October and continues upto December. These crops come to flowering in the month of January and mature by April-May. April-May experience increasing temperatures. With the global warming in place, temperature rises are experienced right from the end of February. Therefore it is essential to look for alternatives particularly to mitigate raising temperatures often referred to as terminal temperature stress during the maturity period. One of the solutions for
this problem is to screen germplasm for their ability to yield even in adverse situations. Stability analysis provides a means for mitigating this problem. The present study was therefore planned to identify such stable genotypes which may tolerate raising temperatures in the grain filling/maturity period. The present investigation is therefore planned to study the genotype x environment interaction in fenugreek particularly with reference to stability of performance in different sowing dates so that fenugreek genotypes suitable for terminal heat stress and drought tolerance can be identified.

MATERIALS AND METHODS

The experiment was carried out at Jobner which is located at 20° 6’ N and 75° 25’ E in sub temperate region, with a defined cool period which is essential for "rabi" crops. For the present investigation, thirty genotypes of fenugreek were selected randomly from the germplasm collection of AICRP on Spices located at S.K.N. College of Agriculture, Jobner. The list of genotypes used in the study are presented in Table 3. The experimental material was evaluated in randomized block design with 3 replications during "rabi" season of 2012-13 in four artificially created environments as given below:

A. Normal date of sowing (D/S: 03.11.2012):
   A.1 Normal irrigation.
   A.2 Moisture stress (For moisture stress condition half the number of irrigation as given in normal environment are given.)
B. Late sown Condition (15 days after Normal date of sowing) (D/S: 18.11.2012)
   B.1 Normal irrigation
   B.2 Moisture stress (For moisture stress condition half the number of irrigation as given in normal environment are given.).

The whole experiment was maintained under drip irrigation. In each environment/replication, each genotype was sown in a plot size 3.0 x 0.3 m² consisting of one row. The row to row and plant to plant distance was kept 30 cm and 10 cm respectively. At the time of maturity 5 plants were randomly selected from each plot and the observations on the characters as listed in Table 1 were recorded. The plot means were used for statistical analyses. ANOVA over the environments was done to look into the variation among the genotypes and the effect of environments on the variation among genotypes for various characters. Simple correlations were estimated to identify the characters which influenced the yield most. The stability analysis was performed according to Eberhart and Russel (1966). AMMI analysis was done using the software developed by CIMMYT (http://apps.cimmyt.org/biometrics/ammi_pls_sas_program).

RESULTS AND DISCUSSION

Environment-wise analysis of variance revealed that significant differences existed among genotypes in each environment for all characters. Pooled analysis of variance indicated significant differences in their effect on the genotypic expression (Table 1). Partitioning of the sum of squares into days to sowing, irrigations and the interaction indicated that all the three parameters were significant for most of the traits which indicated the differential response of genotypes to the environments. Genotypic sum of squares were also significant for all the traits which indicated existence of inherent differences among the genotypes for all the traits studied. The interaction of genotypes with the environments were significant for all most all the traits indicating their differential non linear response to the environments. This indicated a possibility for selection of environment specific of genotypes. Even the higher order of interaction was significant for most of the traits. The ANOVA has amply demonstrated that the genotypes have responded non linearly to dates of sowing and the moisture stress.

Yield is a complex trait and is governed by several component traits. It is therefore easier to select genotypes with high stability to seed yield based on the stability of the component traits. However, it is important to know which of the traits can be regarded as the component traits before they can be used as index traits for seed yield. Therefore, simple correlations were worked based on all the observations over all the environments over the genotypes. The results are presented in Table 2. Seed yield was found positively correlated with number of pods and test weight. Therefore these two traits were considered as component traits of seed yield and the stability analysis of these two traits besides seed yield are presented here.

A number of methods have been proposed to measure the genotype x environment interactions in terms of stability (Finlay and Wilkinson, 1963, Eberhart and Russell, 1966 and Perkins and Jinks, 1968). Of these, method of Eberhart and Russell (1966) is widely used. According to them stability of performance of a variety can be judged on the basis of mean (\(\bar{y}\)), regression coefficient of the variety on environment (b) and deviation from regression (s²'d). It is generally assumed that high yielding varieties with high stability in terms of both the predictable (linear regression) and unpredictable (deviation from regression) stability parameters are not easily be obtainable. Furthermore such varieties will not give desired response to improved package of practices. Eberhart and Russell (1966), therefore, considered a variety with unit regression (b = 1 average stability) and least deviation from regression (S²'d = 0) as a stable one.
TABLE 1. Pooled analysis of variance for various morphological and yield characters.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Days to 50% flowering</th>
<th>Plant height (cm)</th>
<th>Branches per plant</th>
<th>Pods per plant</th>
<th>Pod length (cm)</th>
<th>Seeds per pod</th>
<th>Test weight (g)</th>
<th>Seed yield (g)</th>
</tr>
</thead>
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<tr>
<td>Environment</td>
<td>03</td>
<td>369.475**</td>
<td>10220.227**</td>
<td>7.33**</td>
<td>1458.15**</td>
<td>30.37**</td>
<td>146.44**</td>
<td>941.633**</td>
<td>6530.876**</td>
</tr>
<tr>
<td>Dates of sowing</td>
<td>01</td>
<td>308.025**</td>
<td>9960.703**</td>
<td>7.197**</td>
<td>1345.45**</td>
<td>24.62**</td>
<td>146.306**</td>
<td>38.993**</td>
<td>3904.115**</td>
</tr>
<tr>
<td>Irrigation</td>
<td>01</td>
<td>27.225**</td>
<td>1360.333**</td>
<td>0.132</td>
<td>1005.675**</td>
<td>0.000</td>
<td>0.11</td>
<td>782.045**</td>
<td>2519.363**</td>
</tr>
<tr>
<td>Dates X Irrigation</td>
<td>01</td>
<td>34.225**</td>
<td>1232.840**</td>
<td>0.001</td>
<td>97.032</td>
<td>6.75**</td>
<td>0.023</td>
<td>130.594**</td>
<td>107.398*</td>
</tr>
<tr>
<td>Replication</td>
<td>02</td>
<td>2.703**</td>
<td>54.371</td>
<td>0.585</td>
<td>267.046**</td>
<td>8.114**</td>
<td>0.446</td>
<td>1.561**</td>
<td>111.511**</td>
</tr>
<tr>
<td>Replications X Dates</td>
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<td>1.525**</td>
<td>334.662**</td>
<td>0.197</td>
<td>242.767**</td>
<td>0.141</td>
<td>5.477</td>
<td>1.118</td>
<td>158.053**</td>
</tr>
<tr>
<td>Replications X Irrigation</td>
<td>02</td>
<td>3.325</td>
<td>242.26**</td>
<td>1.031*</td>
<td>93.973</td>
<td>2.013</td>
<td>0.419</td>
<td>0.18</td>
<td>76.555*</td>
</tr>
<tr>
<td>Replication X Dates X Irrigation</td>
<td>02</td>
<td>7.258*</td>
<td>194.893*</td>
<td>0.818</td>
<td>38.873</td>
<td>0.594</td>
<td>11.156**</td>
<td>1.267</td>
<td>25.049</td>
</tr>
<tr>
<td>Genotypes</td>
<td>29</td>
<td>3.014**</td>
<td>205.018**</td>
<td>0.92**</td>
<td>271.502**</td>
<td>1.501**</td>
<td>2.961**</td>
<td>4.101**</td>
<td>66.952**</td>
</tr>
<tr>
<td>Genotypes X Environments</td>
<td>87</td>
<td>2.584**</td>
<td>89.422**</td>
<td>0.401**</td>
<td>139.431**</td>
<td>0.745</td>
<td>2.662**</td>
<td>2.561**</td>
<td>41.672**</td>
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<td>Genotypes X Dates</td>
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<td>3.105</td>
<td>97.775*</td>
<td>0.902**</td>
<td>151.06**</td>
<td>0.610</td>
<td>2.47**</td>
<td>4.219**</td>
<td>56.541**</td>
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<td>Genotypes X Irrigation</td>
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<td>2.397*</td>
<td>90.950**</td>
<td>0.308</td>
<td>135.636**</td>
<td>0.865</td>
<td>1.985</td>
<td>2.804</td>
<td>34.398*</td>
</tr>
<tr>
<td>Genotypes X Dates X Irrigation</td>
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<td>2.248</td>
<td>79.542**</td>
<td>0.263</td>
<td>131.597**</td>
<td>0.942</td>
<td>3.53**</td>
<td>2.661**</td>
<td>34.077*</td>
</tr>
<tr>
<td>Polled error</td>
<td>232</td>
<td>1.556</td>
<td>45.390</td>
<td>0.315</td>
<td>47.75</td>
<td>0.795</td>
<td>1.316</td>
<td>1.236</td>
<td>19.951</td>
</tr>
</tbody>
</table>

*significant at \( p=0.05 \) and ** Significant at \( p=0.01 \)
In order to know the stability of the genotypes, Eberhart and Russel’s (1966) model was applied, the joint regression analysis was done. The results of joint regression analysis are presented in Table 3. The environment + (variety x environment) component was significant for most of the characters excepting for branches per plant. Stability analysis by joint regression analysis (Eberhart and Russell, 1966) revealed that the linear component of G x E interaction was highly significant for all characters excepting branches per plant indicating that genotypes had divergent linear response to the environmental changes for all the characters excepting for branch per plant. Supporting evidence for significant G x E (linear) component as observed in the present study were published by Toshniwal (1984) for plant height, pods per plant, grains per pods and test weight in fenugreek.

The pooled deviation was also significant for all the traits excepting plant height, branches per plant and pod length suggesting that deviations from linear regression also contributed substantially to the differences in stability of the genotypes for these characters. This suggested non-predictable performance of genotypes across the environments. It may be concluded that for seed yield both linear as well as non-linear components were highly significant indicating that both predictable and unpredictable components contributed significantly, towards the differences in stability among different genotypes.

The estimates for seed yield were non-significant for 20 out of 30 genotypes, thus most of the varieties were stable for seed yield. There was positive correlation between mean and b values (Figure 1) indicating that the genotypes which had high yielders were better suited for better environment (normal sowing and full irrigation schedule), while the genotypes with lower means are better suited for poor environments. UM 112, UM 116, UM 128, UM 193, UM 304, RMt 1 and RMt 361 had higher mean, b close to 1 hence were stable. UM 144, UM 202 and UM 302 on the other hand had b significantly higher than 1 was suitable for better environments, i.e. irrigated conditions with normal

![FIG 1: Scatter diagramme between mean and regression coefficient (b) for seed yield per plant.](image)
<table>
<thead>
<tr>
<th>Source</th>
<th>D.f.</th>
<th>Days to 50% flowering</th>
<th>Plant height (cm)</th>
<th>Branches per plant</th>
<th>Pods per plant</th>
<th>Pod length (cm)</th>
<th>Seeds per pod</th>
<th>Test (g)</th>
<th>weight</th>
<th>Seed yield (g)</th>
</tr>
</thead>
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<td>Genotypes</td>
<td>29</td>
<td>1.005**</td>
<td>68.34**</td>
<td>0.307</td>
<td>98.50**</td>
<td>18.966</td>
<td>0.987**</td>
<td>1.701**</td>
<td>22.33**</td>
<td></td>
</tr>
<tr>
<td>Env. + (Gen. * Env.)</td>
<td>90</td>
<td>198.084**</td>
<td>36659.99**</td>
<td>16.675</td>
<td>8996.21**</td>
<td>25.905</td>
<td>48.81**</td>
<td>313.87**</td>
<td>2176.95**</td>
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</tr>
<tr>
<td>Env. (Linear)</td>
<td>01</td>
<td>123.159**</td>
<td>34066.74**</td>
<td>2.444</td>
<td>4852.72**</td>
<td>1299.831**</td>
<td>24.03**</td>
<td>23.96**</td>
<td>475.60**</td>
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<tr>
<td>Gen. * Env. (Linear)</td>
<td>29</td>
<td>32.126**</td>
<td>920.62**</td>
<td>8.625</td>
<td>1560.85**</td>
<td>0.233</td>
<td>0.886**</td>
<td>0.839**</td>
<td>12.21**</td>
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<tr>
<td>Pooled deviation</td>
<td>60</td>
<td>0.714</td>
<td>27.87**</td>
<td>0.094</td>
<td>41.37**</td>
<td>0.129</td>
<td>0.276</td>
<td>1.674**</td>
<td>0.70</td>
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<td>UM-100</td>
<td>02</td>
<td>0.865**</td>
<td>10.30</td>
<td>0.164</td>
<td>02.51**</td>
<td>0.028</td>
<td>0.551</td>
<td>1.510**</td>
<td>22.54**</td>
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<td>UM-112</td>
<td>02</td>
<td>0.060</td>
<td>0.00</td>
<td>0.169**</td>
<td>90.28**</td>
<td>0.123</td>
<td>0.163</td>
<td>0.798**</td>
<td>2.549</td>
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<tr>
<td>UM-116</td>
<td>02</td>
<td>0.187</td>
<td>30.38**</td>
<td>0.013</td>
<td>18.35**</td>
<td>0.939**</td>
<td>0.071</td>
<td>1.324**</td>
<td>14.33**</td>
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<tr>
<td>UM-118</td>
<td>02</td>
<td>0.379</td>
<td>36.57**</td>
<td>0.087</td>
<td>58.96**</td>
<td>0.078</td>
<td>0.825**</td>
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<td>JUM-124</td>
<td>02</td>
<td>1.084**</td>
<td>68.57**</td>
<td>0.024</td>
<td>08.41</td>
<td>0.179</td>
<td>0.343</td>
<td>1.567**</td>
<td>0.187</td>
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<tr>
<td>UM-126</td>
<td>02</td>
<td>0.138</td>
<td>17.40</td>
<td>0.007</td>
<td>07.60**</td>
<td>0.117</td>
<td>0.781**</td>
<td>0.049</td>
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<tr>
<td>UM-127</td>
<td>02</td>
<td>0.779</td>
<td>64.00**</td>
<td>0.039</td>
<td>01.53</td>
<td>0.236</td>
<td>0.607</td>
<td>0.413</td>
<td>0.512</td>
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<td>UM-128</td>
<td>02</td>
<td>0.188</td>
<td>05.84</td>
<td>0.137</td>
<td>21.94</td>
<td>0.024</td>
<td>0.058</td>
<td>0.170</td>
<td>3.374</td>
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<tr>
<td>UM-134</td>
<td>02</td>
<td>0.493</td>
<td>05.53</td>
<td>0.225**</td>
<td>36.64**</td>
<td>0.199</td>
<td>0.376</td>
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<td>19.59**</td>
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<td>UM-136</td>
<td>02</td>
<td>0.059</td>
<td>27.56**</td>
<td>0.034</td>
<td>26.53**</td>
<td>0.023</td>
<td>0.665</td>
<td>0.862**</td>
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<tr>
<td>UM-137</td>
<td>02</td>
<td>0.240</td>
<td>0.97</td>
<td>0.026</td>
<td>26.76</td>
<td>0.213</td>
<td>3.075**</td>
<td>0.317</td>
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<tr>
<td>UM-140</td>
<td>02</td>
<td>0.384</td>
<td>11.82</td>
<td>0.001</td>
<td>01.28</td>
<td>0.002</td>
<td>1.726**</td>
<td>1.264**</td>
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<td>UM-144</td>
<td>02</td>
<td>1.166**</td>
<td>18.39</td>
<td>0.060</td>
<td>16.82</td>
<td>0.016</td>
<td>0.241</td>
<td>1.542**</td>
<td>4.337</td>
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<td>UM-152</td>
<td>02</td>
<td>0.105</td>
<td>08.01</td>
<td>0.175**</td>
<td>353.24**</td>
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<td>UM-163</td>
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<td>1.170**</td>
<td>61.14**</td>
<td>0.005</td>
<td>05.64</td>
<td>0.034</td>
<td>0.165</td>
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<td>0.187</td>
<td>12.72</td>
<td>0.027</td>
<td>18.81</td>
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<td>UM-193</td>
<td>02</td>
<td>0.182</td>
<td>02.84</td>
<td>0.015</td>
<td>08.31</td>
<td>0.084</td>
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<td>0.208</td>
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<td>UM-202</td>
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<td>11.00</td>
<td>0.173</td>
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<td>0.382</td>
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Contd.......

TABLE 3. Joint regression analysis (Eberhart and Russell, 1966) for different characters tested over four environments.
date of sowing. These genotypes were not suitable for adverse environments like late sowing and/or less irrigations. In contrast UM 126, UM 222 were suitable for adverse conditions like late sowing and/or less number of irrigations. Perusal of the stability parameters of the other yield components namely pods per plant, seeds per pod and test weight indicated the following.

Most of the genotypes exhibited significant deviation from regression indicating their instability for pods per plant. However, based on mean and regression coefficient UM-112, UM-118, UM-134, UM-136, UM-152 and UM-353 were the most unstable among all the genotypes, where as UM-137, UM-144, UM-189, UM-202, UM-228 and UM-301 having unit regression (close to 1) and higher number of pods per plant was most stable. UM-124 and UM-140 having below average stability were suited for better management conditions such as irrigated land and normal sowing, while, UM-127, UM-222, UM-322 and RMt-1 with their above average stability were suitable for poor management conditions or in other words may prove better under unirrigated lands or late sowing.

The estimates of nine genotypes significantly deviated from zero for test weight. Most of the genotypes exhibited b value close to 1 indicating their average stability and were thus desirable. UM 325 on the other hand is suitable for poor environments.

Eberhart and Russel’s model assumes linear relationship between the genotypes and environments. If this relationship fails because of interaction, it will be difficult to explain the relationship (Crossa, 1990). The additive nature of the common analysis of variance (ANOVA) allows the description of additive nature of the main effects i.e. genotypes and the environments, their interaction (residue remaining after the main effects) may not be additive. AMMI model allows to combine in a single model the estimation of main effects and multiplicative components for the effects of the GE interaction (Table 4). Hence more precise genotype environment interaction estimates could be obtained with the model that makes it easier to interpret the result obtained (Duarte and Vencovsky, 1999).

Additionally, results from AMMI are useful for performing mega-environment analysis in which a crop’s growing region is subdivided into homogenous subregions that have similar interaction patterns and cultivar rankings, simplifying cultivar recommendations (Zobel et al., 1988).

Partitioning of GEI into principal components indicated that for all the three traits the total GEI was explained by the first two components (IPCA I and II) (Table 1). The IPCA1 scores are plotted against means of genotypes/
TABLE 4 Mean values and stability parameters (b and s’d) of the fenugreek genotypes for seeds yield (g) and other select traits.

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Seed yield (g)</th>
<th>Pods per plant</th>
<th>Test weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>b</td>
<td>S’d</td>
</tr>
<tr>
<td>UM-100</td>
<td>11.78</td>
<td>0.182</td>
<td>7.906</td>
</tr>
<tr>
<td>UM-112</td>
<td>14.53</td>
<td>2.105*</td>
<td>27.153**</td>
</tr>
<tr>
<td>UM-116</td>
<td>13.44</td>
<td>1.210**</td>
<td>-2.827</td>
</tr>
<tr>
<td>UM-118</td>
<td>18.12</td>
<td>1.307</td>
<td>14.846**</td>
</tr>
<tr>
<td>UM-126</td>
<td>16.50</td>
<td>1.241</td>
<td>30.690**</td>
</tr>
<tr>
<td>UM-127</td>
<td>09.07</td>
<td>-0.025++</td>
<td>-6.370</td>
</tr>
<tr>
<td>UM-128</td>
<td>16.11</td>
<td>0.695</td>
<td>9.384**</td>
</tr>
<tr>
<td>UM-134</td>
<td>15.78</td>
<td>1.108**</td>
<td>-5.883</td>
</tr>
<tr>
<td>UM-136</td>
<td>14.82</td>
<td>1.176</td>
<td>22.743**</td>
</tr>
<tr>
<td>UM-137</td>
<td>14.67</td>
<td>0.971**</td>
<td>-5.948</td>
</tr>
<tr>
<td>UM-140</td>
<td>15.26</td>
<td>0.704</td>
<td>5.575</td>
</tr>
<tr>
<td>UM-144</td>
<td>18.68</td>
<td>1.689***++</td>
<td>-5.133</td>
</tr>
<tr>
<td>UM-152</td>
<td>13.75</td>
<td>0.590</td>
<td>-0.146</td>
</tr>
<tr>
<td>UM-163</td>
<td>13.73</td>
<td>0.613</td>
<td>-1.218</td>
</tr>
<tr>
<td>UM-189</td>
<td>12.44</td>
<td>0.844</td>
<td>25.673**</td>
</tr>
<tr>
<td>UM-193</td>
<td>17.34</td>
<td>1.567*</td>
<td>6.014</td>
</tr>
<tr>
<td>UM-202</td>
<td>15.75</td>
<td>1.354***++</td>
<td>-5.877</td>
</tr>
<tr>
<td>UM-222</td>
<td>12.77</td>
<td>0.734***++</td>
<td>-6.573</td>
</tr>
<tr>
<td>UM-228</td>
<td>16.64</td>
<td>1.019</td>
<td>32.196**</td>
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<tr>
<td>UM-301</td>
<td>15.60</td>
<td>0.472</td>
<td>1.967</td>
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<tr>
<td>UM-302</td>
<td>19.30</td>
<td>1.595***++</td>
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<td>UM-304</td>
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<td>UM-321</td>
<td>13.80</td>
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<td>UM-322</td>
<td>16.46</td>
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<td>UM-325</td>
<td>13.15</td>
<td>1.029</td>
<td>14.682**</td>
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<tr>
<td>UM-353</td>
<td>13.78</td>
<td>0.846</td>
<td>13.822**</td>
</tr>
<tr>
<td>UM-354</td>
<td>14.63</td>
<td>0.529</td>
<td>1.913</td>
</tr>
<tr>
<td>RMt-1</td>
<td>16.86</td>
<td>1.242**</td>
<td>-1.973</td>
</tr>
<tr>
<td>RMt-361</td>
<td>19.06</td>
<td>1.806*</td>
<td>11.216**</td>
</tr>
<tr>
<td>average</td>
<td>14.92</td>
<td>3.59</td>
<td>5.56</td>
</tr>
</tbody>
</table>

CD  3.59  5.56  0.89

evironments in (Figure 2). The environments were more variable in comparison to genotypes, as indicated by the wide spread of the environmental values. The mean in first date of sowing with full irrigation was the highest yielding (DI1rr). The yield in second date of sowing with drought (D2Dr) had the least yield as expected. In general the environments can be grouped into two- the first with the first and the second environments while the second consisting of third and fourth environments which were less yielding. Genotypes closer to the point of origin (IPCA scores close to zero) are the stable genotypes. UM- 137, UM-322, RMt-1, UM-128 were the stable genotypes. Among these UM-137 had absolute stability with even mean close to the general mean. UM-112 was the most unstable one with high IPCA score. RMt-361 followed by UM-302, UM-114 and UM-193 were ideal for the first environment, UM-126 was ideal for the fourth environment, the other genotypes for fourth environment were UM-127 and UM-189. The genotypes falling the quarter I (high mean and positive IPCA scores) were suited for the environments falling in that quarter namely I and II. The genotypes viz UM-124, UM-261, UM-118, UM-144, UM-302 and UM-193. While UM-126, UM-189, UM-127, UM-353 and UM-152 belong to this category. The biplot of IPCA1 and IPCA2 scores also corroborated the above results. UM137 was again found to be the stable genotype. Following the vertices and the perpendiculars as suggested by Burgueno et al (2001), UM112 is the winner genotype for environment 1, UM124 for environment 2, UM-126 and UM-100 for environment 4 and UM-228 and UM-189 for environment 3 respectively. Similar results were also noted for pods per plant and test weight.

In conclusion it may said that variation exists with regard to stability of seed yield and its traits in fenugreek when sown either in at optimum time or late sowing or
with full irrigations or drought conditions. There is a positive correlation between mean seed yield and the stability. Similarly the stability of the seed yield is dependent on stability of component traits namely pods per plant and test weight. The stability results corroborated with the results obtained from AMMI analysis with regard to stability, although AMMI analysis provided a better chance to delineate genotypes for their suitability to different environments.

REFERENCES


