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Research Article

Stability analysis in fenugreek (*Trigonella foenum-graecum* L.)

Jyoti Kumari, G.U. Kulkarni and L.K. Sharma
Department of Genetics and Plant Breeding, Junagadh Agricultural University, Junagadh
E-mail: kjyoti199@gmail.com

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Abstract
Thirty genotypes of fenugreek were grown at Instructional Farm, JAU, Junagadh in three different environments created by manipulating dates of sowing during *rabi* season of the year 2012-2013. Stability analysis was carried out to identify phenotypically stable genotypes. Pooled analysis of variance for stability in the performance of different genotypes of fenugreek were significant for all the characters *viz.,* days to 50% flowering, plant height, number of pods per plant, number of seeds per pod, days to maturity and seed yield per plant . Mean square due to G×E was highly significant for all the characters and significant mean square due to environment (linear) indicated the existence of real genotypic differences in characters for regression over environmental mean. On the basis of stability component analysis, four genotypes *viz.,* RMt-1, AFg-1, RMt-143 and AM-326 were found stable for seed yield per plant as having high mean, regression coefficient near to unity and least non-significant deviation.

Key words
Fenugreek, g×e interactions, regression coefficient, stability

Introduction

Fenugreek (*Trigonella foenum-graecum* L.) belongs to family *Fabaceae*, is a diploid species with chromosome number of 2n=16. The genus *Trigonella* is one of the largest genera of the tribe *Trifoliate* in the family *Fabaceae* and sub-family *Papilionaceae* (Balodi and Rao, 1991). Fenugreek which is actually a legume used both as a herb and as a spice. As a matter of fact, after turmeric, fenugreek seeds are the most medically useful item in an Indian kitchen and it is third important seed spice in India after coriander and cumin. In India fenugreek is cultivated in an area of about 81200 ha with production of about 118400 tonnes and productivity of 1458 kg/ha (Anonymous 2011- 12). The low productivity of fenugreek in India is mainly due to low harvest index, low number of flowers and non-availability of suitable high yielding varieties for various agro-climatic regions. In order to evolve a suitable and stable fenugreek variety, it is necessary to test different genotypes in different targeted environments. The relative performance of cultivars for quantitative traits like yield, varies from one environment to another and interaction between genotype x environment has an important impact on the improvement of varieties (Allard and Bradshaw, 1964). Therefore, extensive testing is needed to identify genotypes that show minimum interaction with the environment. The present study was conducted to evaluate and identify the fenugreek varieties with wider adaptation over a range of environments using various stability parameters.

Materials and methods

Experimental material for present investigation comprised of thirty genotypes of fenugreek collected from the National Research Centre on Seed Spices (ICAR), Tabiji, Ajmer (Rajasthan). The genotypes were sown in a randomized block design (RBD) with, three replications during *rabi* season of the year 2012-2013, at Instructional farm, JAU Junagadh. Three different environments were created by sowing the genotypes at the interval of 20 days *viz.,* 17th November, 8th December and 29th December 2012. Observations were recorded on five randomly selected plants per genotype per replication in each environment for plant height, number of pods per plant, number of seeds per pod and seed yield per plant, whereas days to 50% flowering and days to maturity were recorded on plot basis. The analysis of variance was carried out for individual as well as over the environments as per standard procedure given by Panse and Sukhatme (1985).

The regression analysis of thirty genotypes six characters was carried out using the model given by Eberhart and Russell, 1966. Then, stability parameters, phenotypic index (P_i), regression coefficient (b_i), deviation from regression (S^2_{di}) of thirty genotypes were computed as per the method suggested by Finlay and Wilkinson (1963) and further amplified and generalized by Eberhart and Russell (1966).

Results and discussion

The analysis of variance in each of the three environments indicated significant differences among the genotypes for all the six characters in three environments (Table 1). The pooled analysis of variance for different characters revealed significant differences among the genotypes, environments and genotype × environment interaction for all the characters, indicating the existence of considerable variability in the materials studied and between the environments (sowing dates). Component analyses of environment + (genotype × environment) were significant for all the traits. Partitioning of this variation into linear and non-linear component revealed that the mean square due to environment (linear) were significant for all the traits. The significant mean square confirm that the environment were random and different and they exercised influence on expression of traits and this variation could have arisen due to linear response of regression of the cultivar to the environment. The mean square due to the G × E (linear) were significant for all characters revealed that the behavior of genotype could be predicted over the environment more precisely and accurately as the G × E interaction was the outcome of the linear function of the environmental components. The non-linear component arising due to heterogeneity measured as mean square due to the pooled deviation was significant for all the traits except 100 seed weight revealed the presence of non-linear response of the genotypes to the changing environment for these traits. The significant of pooled deviation confirms contribution of non-linear component to the total G × E interaction. The genotype differed with respect to stability of these traits making its prediction more difficult. However, the magnitude of linear component *i.e.* environment (linear) and genotype × environment (linear) was many time higher than the non linear component for most of the characters revealed that the prediction of stability could be reliable though it may get affected to some extent. The results obtained in present study are in agreement with the finding of Kole 2005 and Gangopadhyay *et al.* (2012).

In the present study, the mean ($\bar{g}$) phenotypic index ($P_i = \bar{g} - \bar{X}$), linear regression (b_i) and deviation from regression (S^2_{di}) of all the traits studied are presented in table 2.

Early flowering (-ve P_i value) genotypes *viz.*, GM-2, RMt-1, Afg-2 found most stable since they show regression coefficient (0.73, 0.85, 1.58) near to unity and least non-significant deviation from regression. Genotypes *viz.*, RMt-305, AFg-3 and RMt-143 exhibited lower mean height than population mean (-ve P_i value) and were found most stable as having regression coefficient near to unity while the genotypes which showed higher mean value (+ve P_i value) for pods per plant over three environments were RMt-1, RMt-351, AM-329 and Afg-2. Out of them, RMt-1, RMt-351 and AM-329 were found most stable, since they showed regression coefficient value (1.49, 1.12, 1.13) respectively) near to unity and least non-significant deviation from regression.

Eleven genotypes had higher mean value than population mean ($^{+ve}$ P_i value) so were suitable for breeding for number of seeds per pod. However from stability point of view AM-288, LAM Selection-1 and AM-202 were found most stable over variable environment as having regression coefficient (1.05, 1.55, and 0.88, respectively) around unity and least non-significant deviation from regression. Late maturing genotype AM-324 (+ve P_i value) was high responsive (b_i>1) so suitable for rich environment only, while, Hissar Madhavi, AM-327-2 and Afg-2 were above average stable as having b_i value below unity and low deviation from regression. Early maturing (-ve P_i value) genotypes *viz.*, RMt-305, AM-288, AM-326, CO-2, Afg-1, AM-578, AM-329, UM-344 and Afg-3 exhibited average stability over environment as having regression coefficient near to unity and least non significant deviation from regression. However LAM Selection -1 was high responsive (b_i>1) so suitable for favourable environment only.

Estimates of stability parameters revealed that out of thirty genotypes, nineteen genotypes showed predictable behaviour for seed yield per plant as they exhibited non-significant deviation from regression. Among them only six genotypes had higher mean than population mean (+ve P_i value), out of which RMt-143 exhibited highest mean and regression coefficient (1.36) around unity so it was found stable over varying environment. Genotypes RMt-1 and Afg-1were also found most stable over different environment as having regression coefficient value (0.88, 0.70 respectively) near to unity, mean value higher than population mean and least non-significant deviation from regression. However, the genotype, AM-326 had regression coefficient (0.87) near to unity and mean value equal to population mean (P_i=0) hence this genotype was also suitable for cultivation over varying environment. Genotypes *viz.*, AM-324 and Rajendra Kranti were suitable for rich environment only since they showed regression coefficient significantly higher than unity. Result of the present study based on mean performance, phenotypic index, regression coefficient for seed yield per plant for genotypes and non-significant deviation from regression are graphically represented in fig 1.

From this analysis it was concluded that, stable genotypes that can be used directly for breeding programme are GM-2, RMt-1 and Afg-2 for early flowering, LAM Selection-1 and AM-578 for plant height, Rmt-1, RMt-351 and AM-329 for improvement of number of pods per plant, AM-288, LAM Selection-1 and AM-202 for number of seeds per pod, RMt-305, AM-288, AM-326, CO-2, Afg-1, AM-578, AM-329, UM-344 and Afg-3 for early maturity. However for seed yield per plant the genotypes, RMt-1, Afg-1, AM-326 and RMt-143 were found most stable and suitable for average environment. From present analysis it seems that days to 50% flowering, plant height, number of pods per plant, number of seeds per pod and days to maturity varies in imparting yield

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stability in the diverse genotypes which constituted the material of this study.

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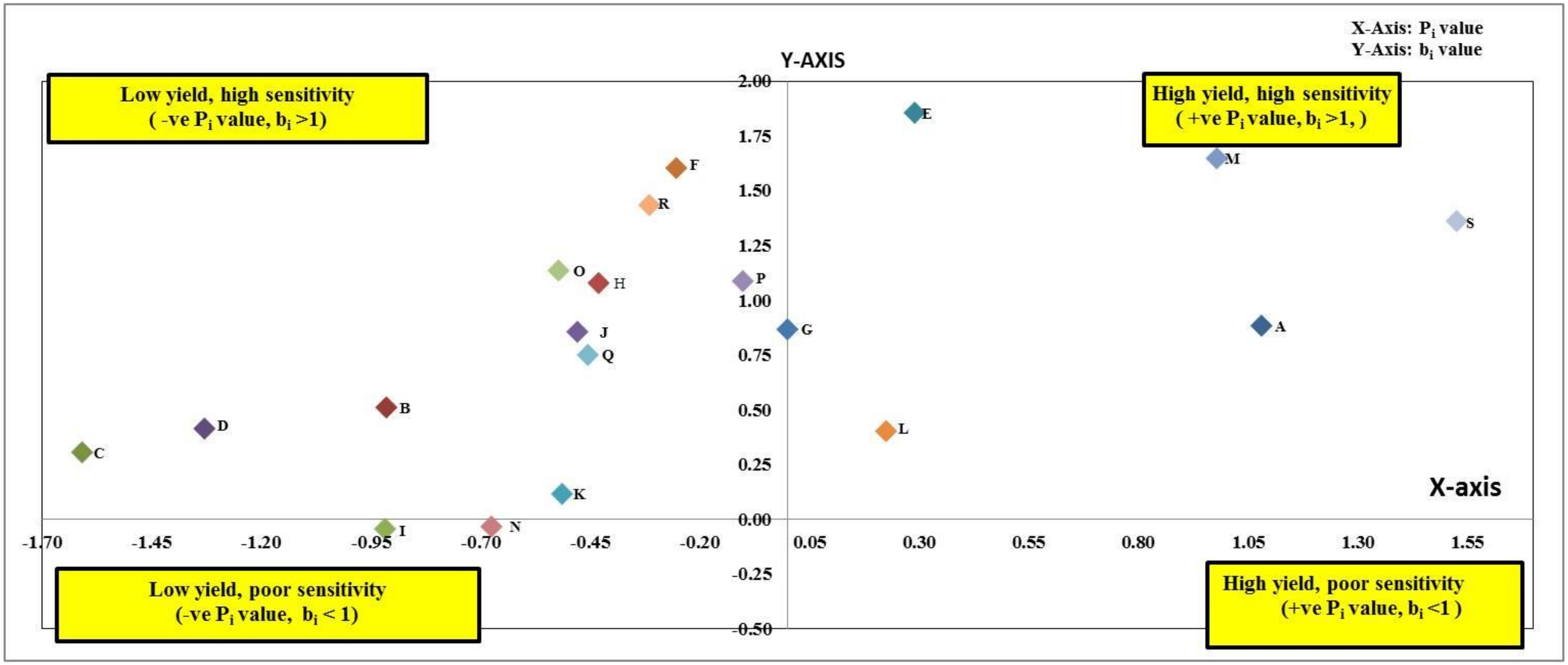
Fig. 1. Adaptive specificities of genotypes which show non-significant deviation from regression for seed yield per plant in fenugreek



A- RMt-1 **B**-Azad Methi **C**-RMt-305 **D**-AM-327 **E**-AM-324 **F**-AM-328 **G**-AM-326 **H**-LAM Selection-1 **I**-Hissar Madhavi **J**-AM-202
K-CO-2 **L**-Afg-1 **M**-Rajendra Kranti **N**-Hissar Mukta **O**-Hissar Suvarna **P**-RMt-351 **Q**-AM-578 **R**-Afg-3 **S**-RMt-143

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Table 1. Analysis of variance for phenotypic stability in fenugreek

Source of Variation	d.f.	Days to 50% flowering	Plant height (cm)	Number of pods per plant	Number of seeds per pod	Days to maturity	Seed yield per plant (g)
Genotypes	29	$17.296^{**++\#\#}$	$35.492^{*++\#\#}$	$43.770^{**++\#\#}$	$8.13^{**++\#}$	$15.39^{**++\#\#}$	$1.96^{**++\#\#}$
Environment	2	$324.471^{**++\#\#}$	$824.694^{**+\#\#}$	$721.468^{**++\#}$	24.33^{**++}	$1082.68^{**++\#\#}$	$17.36^{**++\#\#}$
Geno. X Env.	58	6.671^{**}	$18.500^{**\#\#}$	17.879^{**}	3.61^{**}	4.919^{**}	0.539^{**}
Env. + (Gen. X Env.)	60	$17.265^{**++\#\#}$	$45.373^{**++\#\#}$	$41.331^{**++\#}$	$4.300^{**++\#\#}$	$40.844^{**++\#\#}$	$1.100^{**++\#}$
Environment (Linear)	1	$648.941^{**++\#\#}$	$1649.389^{**++\#\#}$	$1442.937^{**++\#\#}$	48.653^{**}	$2165.350^{**++\#\#}$	$34.715^{**++\#\#}$
Geno. X Env. (Linear)	29	8.285^{**}	$31.085^{**+\#\#}$	12.851^{**}	2.303^{**}	4.104^{**}	0.488^{**}
Pooled deviation	30	4.888^{**}	5.719^{**}	22.143^{**}	4.753^{**}	5.543^{**}	0.571^{**}
Pooled error	174	1.25	0.766	2.074	0.833	0.897	0.064

+, ++ Significant at 5 and 1 per cent levels, respectively when tested against G x E
#, ## Significant at 5 and 1 per cent levels, respectively when tested against pooled deviation
*, ** Significant at 5 and 1 per cent levels, respectively when tested against pooled error

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Table 2. Mean performance and stability parameters for different characters in fenugreek

S. No.	Genotypes	Days to 50% flowering				Plant height				Number of pods per plant			
		Mean	P_i	b_i	S^2_{di}	Mean	P_i	b_i	S^2_{di}	Mean	P_i	b_i	S^2_{di}
1	GM-2	41.94	-1.63	0.73	0.61	37.79	0.58	1.43	8.19**	19.43	-0.31	1.19	1.52
2	RMt-1	43.56	-0.02	0.85	2.99	38.93	1.72	1.67**	-0.75	25.61	5.87	1.50	1.42
3	Azad Methi	42.82	-0.76	0.98	6.37*	32.49	-4.72	0.00**	-0.68	17.82	-1.91	0.82**	-1.85
4	RMt-305	44.22	0.64	-0.04*	3.24	35.97	-1.24	1.37	1.62	12.82	-6.91	0.38**	-2.01
5	AM-327	47.22	3.64	0.48	11.49**	36.94	-0.27	1.40*	0.75	15.16	-4.58	0.42*	1.48
6	AM-324	44.06	0.48	0.68	9.33**	35.38	-1.83	1.66*	4.69**	17.85	-1.88	1.06	0.20
7	AM-328	48.44	4.87	0.28	4.40*	29.61	-7.60	-0.68**	-0.35	16.80	-2.94	0.62	58.89**
8	Hissar Sonali	45.72	2.14	0.93	0.29	40.96	3.75	1.29	7.31**	26.67	6.94	1.64	19.10**
9	AM-288	44.67	1.09	0.35**	-1.05	31.48	-5.73	-0.52*	18.09**	17.38	-2.35	0.61	11.39*
10	AM-326	42.33	-1.25	0.44**	-0.79	33.62	-3.59	-0.19**	0.03	18.60	-1.13	0.79	4.19
11	LAM Selection-1	42.39	-1.19	0.06**	-1.19	37.47	0.26	1.01	1.86	16.93	-2.81	0.49	11.81*
12	Hissar Madhavi	44.22	0.64	0.14**	0.16	37.03	-0.18	1.59**	-0.72	12.48	-7.25	-0.05**	2.79
13	AM-327-2	46.06	2.48	0.93	-0.65	32.17	-5.04	-0.28**	-0.74	21.56	1.83	1.66	6.01*
14	AM-202	45.50	1.92	1.39	8.75**	46.78	9.57	0.59**	-0.54	19.57	-0.16	0.93	-1.75
15	CO-2	42.00	-1.58	0.61**	-1.21	36.14	-1.07	1.00	6.33**	17.48	-2.25	0.60	1.09
16	Afg-1	43.33	-0.25	0.35**	-0.41	36.99	-0.22	1.39**	0.43	18.52	-1.21	0.50	2.34
17	Rajendra Kranti	46.44	2.87	0.83	6.43*	42.64	5.43	1.34	26.96**	20.93	1.20	0.66	9.61*
18	Hissar Mukta	42.78	-0.80	1.61	7.45**	39.50	2.29	1.80*	7.19**	13.63	-6.11	-0.05**	-0.12
19	Hissar Suvarna	42.89	-0.69	1.81**	-1.13	38.03	0.82	1.93**	0.09	21.64	1.90	1.39	9.97*
20	Afg-2	43.50	-0.08	1.58	1.12	37.44	0.23	0.78	18.13**	23.17	3.44	1.57**	-1.55
21	RMt-351	45.44	1.86	1.42	15.64**	40.11	2.90	1.60	18.57**	22.87	3.13	1.12	5.80
22	AM-578	42.83	-0.75	0.97	3.99*	37.50	0.29	0.96	0.46	19.76	0.03	1.61	21.30**
23	Pant Ragini	46.33	2.75	0.95	19.41**	35.76	-1.45	2.10	19.99**	23.86	4.12	0.64	189.90**
24	Afg-6	47.11	3.53	0.99	2.57	41.56	4.35	1.36	4.55**	24.13	4.39	1.83	75.17**
25	AM-329	38.89	-4.69	1.46**	-0.92	39.17	1.96	-0.10**	1.35	21.56	1.82	1.13	1.94
26	Afg-5	41.11	-2.47	2.32	13.52**	35.31	-1.90	1.16*	-0.47	19.28	-0.46	1.27	38.41**
27	UM-344	39.78	-3.80	1.87**	-0.59	38.89	1.68	0.63**	-0.10	18.49	-1.25	1.44	69.28**
28	Afg-4	41.44	-2.13	1.25**	-1.15	37.58	0.37	1.51**	0.97	24.05	4.32	1.44	21.31**
29	Afg-3	39.33	-4.25	2.10**	-1.15	36.06	-1.15	0.89	3.75	17.30	-2.43	1.26	25.86**
30	RMt-143	41.00	-2.58	1.66**	-1.13	36.97	-0.24	1.28	1.59	26.68	6.94	1.55	18.83**
	G.M.	**43.58**	**0.00**	**1.00**	**3.55**	**37.21**	**0.00**	**1.00**	**4.95**	**19.73**	**0.00**	**1.00**	**20.08**
	S.Em ±	**1.55**				**1.69**				**3.32**			

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

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Table 2. Contd.,

S. No.	Genotypes	Number of seeds per pod				Days to maturity				Seed yield per plant			
		Mean	P_i	b_i	S^2_{di}	Mean	P_i	b_i	S^2_{di}	Mean	P_i	b_i	S^2_{di}
1	GM-2	13.35	-0.36	1.34*	-0.81	89.89	-2.46	0.65	6.76**	2.59	-0.15	1.16	0.21*
2	RMt-1	12.92	-0.79	1.09	-0.55	91.67	-0.68	1.09	10.38**	3.82	1.08	0.88	-0.03
3	Azad Methi	13.29	-0.42	0.68	-0.37	91.44	-0.90	0.78	4.53*	1.83	-0.91	0.51**	-0.06
4	RMt-305	9.71	-4.00	0.79**	-0.83	91.56	-0.79	1.04	-0.09	1.13	-1.61	0.31**	-0.06
5	AM-327	8.80	-4.91	0.89	-0.35	94.67	2.32	0.93	17.01**	1.41	-1.33	0.41**	-0.06
6	AM-324	15.69	1.98	1.81	3.65*	94.11	1.77	1.42*	1.38	3.03	0.29	1.86**	-0.06
7	AM-328	13.44	-0.27	4.11	36.53**	94.22	1.88	1.43	3.99*	2.49	-0.25	1.60**	-0.00
8	Hissar Sonali	12.93	-0.78	3.69	17.70**	94.00	1.66	1.26	3.19*	4.97	2.23	2.77	1.13**
9	AM-288	14.64	0.93	1.04	2.34	91.22	-1.12	1.23	1.38	3.14	0.40	0.59	1.64**
10	AM-326	13.13	-0.58	1.22	-0.81	89.89	-2.46	1.04	1.22	2.74	0.00	0.87	0.12
11	LAM Selection-1	14.36	0.65	1.55	1.30	90.33	-2.01	1.29**	-0.77	2.31	-0.43	1.08	0.01
12	Hissar Madhavi	14.09	0.38	0.27	0.62	93.11	0.77	0.45**	-0.77	1.82	-0.92	-0.04	0.12
13	AM-327-2	14.13	0.42	-1.19	3.95*	95.44	3.10	0.69**	-0.62	3.24	0.50	1.14	1.93**
14	AM-202	14.47	0.76	0.88	-0.76	93.67	1.32	0.79	25.79**	2.26	-0.48	0.86	-0.04
15	CO-2	15.00	1.29	-0.52	0.66	91.67	-0.68	1.05	0.60	2.23	-0.51	0.12	-0.02
16	Afg-1	14.53	0.82	0.26	1.73	91.11	-1.23	1.11	2.04	2.96	0.22	0.70	0.03
17	Rajendra Kranti	14.80	1.09	2.61*	0.04	93.67	1.32	1.09	2.88*	3.72	0.98	1.65*	0.01
18	Hissar Mukta	13.77	0.06	0.25	2.30	91.33	-1.01	1.09	7.43**	2.07	-0.68	-0.03	0.05
19	Hissar Suvarna	16.00	2.29	0.36**	-0.71	93.56	1.21	1.29	5.27**	2.22	-0.52	1.14*	-0.06
20	Afg-2	13.76	0.05	0.64	14.64**	93.44	1.10	0.78**	-0.89	2.90	0.16	1.50	0.29*
21	RMt-351	14.47	0.76	1.26	3.88*	96.78	4.43	0.79	4.77*	2.64	-0.10	1.09	-0.06
22	AM-578	9.89	-3.82	2.10	5.13**	90.89	-1.46	1.13	1.29	2.28	-0.46	0.75*	-0.05
23	Pant Ragini	14.20	0.49	1.23	7.63**	95.89	3.54	0.77	10.20**	3.11	0.37	-0.05	6.59**
24	Afg-6	14.16	0.44	-0.76	3.42*	96.11	3.77	0.69	4.89*	2.37	-0.37	0.93	1.01**
25	AM-329	14.83	1.12	1.68	4.12*	88.33	-4.01	0.96	-0.85	3.00	0.26	1.39	0.21*
26	Afg-5	14.27	0.55	1.35	2.46*	90.67	-1.68	1.19	7.58**	2.76	0.02	0.97	1.08**
27	UM-344	15.76	2.04	-0.56*	-0.26	87.89	-4.46	1.04	-0.71	2.87	0.13	1.96	0.98**
28	Afg-4	13.87	0.16	1.65	2.01	90.33	-2.01	0.82	2.72*	3.62	0.88	1.40	0.42**
29	Afg-3	13.51	-0.20	1.31	4.80*	90.44	-1.90	0.97	0.04	2.42	-0.32	1.44**	-0.06
30	RMt-143	13.56	-0.16	-0.32	3.99*	93.00	0.66	1.07	18.72**	4.27	1.52	1.08	-0.06
	G.M.	**13.71**	**0.00**	**1.00**	**3.92**	**92.34**	**0.00**	**1.00**	**4.65**	**2.74**	**0.00**	**1.00**	**0.51**
	S.Em ±	**1.54**				**1.67**				**0.53**			

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