



Stability, correlation and path analysis for seed yield and yield-attributing traits in clusterbean (*Cyamopsis tetragonoloba*)

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Received: 27 July 2009; Revised accepted: 21 January 2011

ABSTRACT

Stability parameter, correlation and path analysis were studied during rainy (*kharif*) seasons of 2005, 2006 and 2007 among 40 genotypes of clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] for yield-related characters. The genotype × environment interaction was highly significant for all the traits studied and a large portion of the interaction was accounted for by the linear components for all the traits. 'CAZG 6', 'RGC 1029', 'GAUG 003', 'GAUG 005', 'RGC 1002', 'HGS 880', 'CAZG 50', 'RGC 1030', 'RGM 114', 'WSP 50', 'HGS 02-1' and 'CLBH 201' were stable for favourable environments while 'VIKAS 35', 'RGC 1038', 'RGC 1076' and 'GAUG 004' were better performing and stable under unfavourable environment for seed yield and yield-attributing traits. The highest correlations were found with seed yield and pods/plant ($r = 0.89$), seeds/pod ($r = 0.53$), secondary branches/plant ($r = 0.49$), plant height ($r = 0.48$) and primary branches/plant ($r = 0.29$). Path analysis indicated the highest direct and positive effect of pods/plant (0.85), seeds/pod (0.28) and 100-seed weight (0.23) on seed yield. The study validates that the number of pods and number of branches are important characters for improvement of seed yield in clusterbean.

Key words: Clusterbean, Environmental index, $G \times E$ interaction, Interrelationship, Stability analysis

Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] is a hardy, drought resistant leguminous herb having deep rooted system and highly adapted in poor and erratic rains of arid and semi-arid parts of the world requiring low inputs and less care. It is cultivated in rainy (*kharif*) season mainly as rainfed crop in the dry habitats. India is one of the major producers of clusterbean and large quantity of its gum is exported to other countries. India accounts for 80% of the total guar produced in the world. Rajasthan occupies the largest area under guar cultivation (82.1%), followed by Haryana (8.6%), Gujarat (8.3%) and Punjab (1%) which in turn produced 64, 22, 12 and 2% guar seeds, respectively (Pathak *et al.* 2010). The average productivity of crop (kg/ha) was 272 in Rajasthan, 881 in Haryana, 522 in Gujarat and 778 in Punjab, respectively (Pathak *et al.* 2009). The climate of western Rajasthan is very fluctuating having erratic, low rainfall and high temperature, which affect the productivity of the crop. The multi-uses of gum present in

guar seed brought its way to the crop of major prominence. Crop productivity can be maximized by planting high-yielding varieties having higher degree of adaptability. The genotype × environment ($G \times E$) interaction had immense importance in breeding programmes for identifying stable genotypes that are widely or specifically adapted to unique environments (Verma *et al.* 2008). Various workers emphasized the importance of genotypes over environment, the linear regression of the genotypes over environmental index and the deviation from regression coefficient for determination of stability and adaptation of the genotypes for seed yield and other important seed yield-influencing traits in clusterbean (Chaudhary *et al.* 2005). Stability parameters along with the knowledge of interrelationship of plant characters with seed yield plays significant role for improvement of yield for which the direct selection is not much effective. Present investigation was carried out to identify stable and high-yielding genotypes of clusterbean for cultivation in the western Rajasthan through stability analysis and to understand the type of association among characters and the extent and nature of direct and indirect effect of component traits on seed yield.

MATERIALS AND METHODS

Forty genotypes including three released varieties were

Based on a part of PhD thesis of the first author submitted to Jai Narain Vyas University during 2008

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evaluated during rainy (*khari*) seasons of 2005, 2006 and 2007 at central research farm, Central Arid Zone Research Institute, Jodhpur (at 27°18'N latitude, 73°01' E longitude and 224 m above sea level). An experiment on each environment was conducted in randomized block design with three replications. The soil was sandy loam in texture having low organic matter (0.12%) and available nitrogen (170 kg/ha), medium in available phosphorus (21 kg P₂O₅/ha) and potassium (270 kg K₂O/ha) with a pH of 8.3. The crop was grown under rainfed conditions with basal dose of 20 kg N and 40 kg P₂O₅/ha. The annual rainfall during cropping season of 2005, 2006 and 2007 (July to October) was 236, 241 and 234 mm, respectively. The plot size for each accession was 3 m×0.9 m where in row-to-row and plant-to-plant spacing of 30 cm and 10 cm, respectively. Data was recorded on plant height, primary branches/plant, secondary branches/plant, seeds/pod, number of pods/plant, 100-seed weight, seed yield/plant, endosperm and gum content on the basis of five randomly selected plants and for days to 50% flowering data were recorded on plot basis. Stability parameters for days to 50% flowering, number of pods/plant, 100-seed weight and seed yield/plant were computed using the regression approach of Eberhart and Russel (1966). Data were subjected to phenotypic correlation and path analysis.

RESULTS AND DISCUSSION

The combined analysis of variance (Table 1) revealed significant differences among the genotypes and environments for all the traits suggesting the presence of variability both among genotypes and environments. The mean squares due to G × E interaction was significant for days to 50% flowering, pods/plant, 100-seed weight and seed yield/plant indicating differential response of genotypes to different environment. Significant mean squares due to environment (linear) indicated considerable difference among environments and their predominant effects on all the traits. Pooled deviation was significant for all the traits except 100-seed weight, indicating the importance of non-linear component in the manifestation of G × E interaction of these significant traits. Significant G × E interaction

(linear) components against pooled error for pods/plant, seed yield/plant and days to 50% flowering revealed that linear regression was the major component responsible for differences in stability whereby the performance can be predicted for these traits with some reliance under different environments, however, for the unpredicted traits predictions can be made by considering the stability parameter of individual genotypes. Similar interactions for these traits have been reported earlier in clusterbean (Chaudhary *et al.* 2005, Henry and Mathur 2006) and in wheat (Gowda *et al.* 2010).

Environment indices

Environment indices indicated that 2005 was favourable environment, particularly for number of pods/plant, seed yield/plant as compared to 2006 and 2007. Though plant is a single developmental unit, but different traits get expressed in different phases and drought conditions at the beginning or middle or end of the crop season affect the traits differently. In 2005 there was stress from mid season onwards (ie 32nd week) that continued up to end of the cropping season. In 2006 there was early stress of medium magnitude from very beginning (27 to 37th week) and during 2007 stress was in pulses between 27 to 30th week, 31 to 34 and 33rd week onwards. It appears that late rains as received in 2006 affected seed yield but on the contrary frequent drought stress during 2007 also affected seed yield and its contributing traits

Stability parameters

Eberhart and Russel (1966) suggested a stable genotypes having regression coefficient approximately to unity ($b_i=1$), higher mean performances and deviation from regression (s^2_{di}) as small as possible. 'HGS 02-1', 'CLBH 201', 'CAZG 6', 'CAZG 50', 'RGC 1029', 'GAUG 003', 'GAUG 005', 'RGC 1002', 'HGS 880', 'RGM 114', 'HGS 884' and 'RGC 986' recorded seed yield/plant more than population mean, b_i values > 1 and non-significant s^2_{di} values, indicating their stability and adaptation to specific favourable environments for seed yield (Table 2), while 'VIKAS 35', 'HGS 891', 'RGC 1038', 'RGC 1077', 'RGC 1076', 'RGC 1055' and 'GAUG 004' recorded with more seed yield, $b_i < 1$ and non-significant

Table 1 Pooled analysis of variance

Source of variance	Df	Seed yield/ plant (g)	Pods/plant	100-seed weight (g)	Days to 50% flowering
Genotypes	39	7.326 **	116.604 **	0.029 ** \$	6.759 **
Environment + G × E	80	8.087 **	78.933 **	0.072 ** \$	14.529 ** \$
Environments	2	112.434** \$	318.712 **	2.021 ** \$	378.175 ** \$
G × E	78	5.412 **	72.785 **	0.022 ** \$	5.204 **
Environments (Lin.)	1	224.869** \$	637.423 ** \$	4.042 ** \$	756.351 ** \$
G × E.(Lin.)	39	5.26 **	15.376	0.036 ** \$	3.611 **
Pooled deviation	40	5.424 **	126.940 **	0.008	6.628 **
Pooled error	234	1.629	27.756	0.011	0.626

** $P=0.01$, * $P=0.05$ against pooled error, \$\$ $P=0.01$, \$ $P=0.05$ against pooled error

Table 2 Mean performance and stability parameters in 40 genotypes of clusterbean

Genotype	Pods/plant			100-seed weight (g)			Seed yield/plant (g)			Days to 50% flowering		
	Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di	Mean	bi	s ² di
'AVKG 73'	28.22	0.47	-52.20	3.01	1.47	0.00	7.20	1.38	-3.99	31.22	0.72	13.93**
'CAZG 50'	32.56	2.20	-35.08	2.86	1.05	0.00	9.23	1.79	-0.94	32.11	0.96	-0.58
'CAZG 6'	27.67	2.03	-101.96	3.03	1.16	0.00	8.01	2.15	-4.75	31.11	0.71	11.98**
'CLBH 201'	38.22	0.12	32.25	2.92	0.86	-0.01	9.38	2.26	-1.38	33.22	1.46	-0.22
'GAUG 0001'	24.89	-0.01	2.48	2.78	0.63	-0.01	6.02	1.01	0.17	33.56	1.38	0.49
'GAUG 0013'	31.22	0.10	-21.02	2.76	0.91	0.03	6.51	0.98	-2.27	31.11	0.64	-0.79
'GAUG 003'	35.11	0.53	337.12*	2.88	1.58	-0.01	9.17	2.7	9.23	33.33	1.38	-0.81
'GAUG 004'	44.89	0.31	151.84	2.79	0.72	-0.01	10.48	0.97	4.28	34.56	1.29	23.73**
'GAUG 005'	35.56	0.77	122.02	3.07	2.34*	-0.02	9.20	3.08	1.53	30.33	0.50	1.06
'GAUG 0101'	26.11	2.01	-63.10	2.82	0.49	-0.01	6.79	0.69	-2.24	31.56	0.75	10.58**
'GAUG 9703'	28.56	1.58	86.41	2.72	0.22	-0.01	6.51	-0.14	0.98	33.44	1.26	0.81
'GAUG 9808'	22.44	0.95	-107.57	2.84	1.31	0.00	5.84	0.68	-5.27	32.56	0.63	-1.08
'HG 155-156'	30.33	0.24	-0.05	2.90	1.27	-0.02	7.27	1.49	-2.16	32.33	0.79	1.20
'HGS 02-1'	38.89	0.33	-18.19	2.86	0.04	-0.01	9.50	1.76	-4.87	31.22	0.57	9.35**
'HGS 02-20'	21.22	1.00	-109.79	2.78	0.22	-0.01	5.21	0.54*	-5.45	31.33	0.51	8.96**
'HGS 02-29'	32.11	-0.69	-95.36	2.90	0.36	0.01	6.10	-0.55	-5.36	31.67	0.66	3.37*
'HGS 26-01'	27.11	2.19	-106.23	2.82	0.56	-0.01	5.73	0.60	-5.04	30.33	0.48	2.62
'HGS 365'	30.78	0.57	-104.32	2.86	0.61	-0.01	6.89	-0.06	-5.35	29.78	0.44	0.88
'HGS 870'	42.11	2.74	599.76*	2.72	0.97	-0.01	9.33	0.02	19.63*	33.56	1.41*	-1.11
'HGS 880'	29.78	1.98	-73.50	2.99	2.03	-0.01	8.28	1.57	-3.81	32.33	1.09	4.14*
'HGS 884'	33.56	0.15	13.66	2.67	1.63	-0.01	8.67	2.25	0.01	33.89	1.67	7.39**
'HGS 891'	31.67	0.36	-107.88	2.97	1.31	-0.01	8.32	0.71	-5.44	30.78	0.49	3.7*
'RGC 1002'	44.33	0.49	62.34	2.90	2.25	-0.01	10.97	2.29	12.78	35.00	1.58	5.23*
'RGC 1029'	37.67	1.67	-73.71	2.87	1.16	-0.01	8.79	2.05	-5.4	32.78	1.26	0.81
'RGC 1030'	34.56	2.39	72.10	2.88	1.46	0.00	7.58	0.78	-2.39	33.33	1.38	-0.81
'RGC 1033'	30.11	1.77	190.58	2.74	0.78	-0.01	6.99	-0.19	11.31	33.33	1.35	2.07
'RGC 1038'	36.78	0.70	310.22	2.79	0.46*	-0.02	8.32	-0.78	3.61	30.78	0.57	5.21*
'RGC 1055'	40.00	2.37	196.36	2.79	0.62	0.00	9.32	0.83	3.02	33.33	1.39	18.26**
'RGC 1059'	23.11	1.75	-109.88	2.88	0.78	-0.01	5.56	1.19	-5.00	30.89	0.67	8.48**
'RGC 1076'	38.89	0.40	-98.31	2.57	-0.52*	-0.02	8.31	-0.08	-5.38	31.44	0.85	-0.41
'RGC 1077'	28.67	0.88	-108.84	2.86	1.30	-0.01	9.54	-0.07	12.22	30.78	0.42	11.64**
'RGC 1078'	21.11	0.65	-52.55	2.89	1.67	-0.01	4.91	0.74	-2.53	34.56	1.85	6.34*
'RGC 1088'	39.67	1.31	525.62*	2.95	1.11	0.01	9.76	-0.56	23.22*	30.44	0.49	3.7*
'RGC 1092'	32.67	0.82	-36.56	2.77	1.00	-0.01	7.47	-0.01	-2.74	31.00	0.60	-0.98
'RGC 2021'	23.22	2.08	-92.51	2.85	0.37*	-0.02	5.37	0.80	-2.19	33.67	1.40	-0.10
'RGC 986'	34.56	1.84	-108.96	2.77	1.43	-0.01	8.14	1.73	-5.39	35.78	1.31	4.20*
'RGM 114'	29.78	1.36	-97.91	2.89	1.27	0.02	7.99	2.56	-5.22	30.78	0.65	6.94**
'RGM115'	26.67	1.80	-106.99	2.8	1.42	0.03	5.96	1.27	-4.38	33.33	1.27	-0.94
'VIKAS 35'	39.22	-2.01	-63.11	2.91	1.29	-0.02	9.18	0.92	0.57	34.44	1.92	41.49**
'WSP 50'	32.44	-0.22	-81.15	2.87	0.42	-0.01	7.58	0.67	-4.62	32.67	1.24	10.09**
Population mean	32.16		2.85			7.78			32.32			

** $P=0.05$, * $P=0.01$, bi= regression coefficient, s²di =deviation from regression coefficient

s²di values which indicated their better performance, high stability and adaptation to unfavourable environmental conditions.

'CAZG 50' and 'RGC 1030' recorded more pods/plant than population mean, bi values > 1 and non-significant s²di values indicating adaptation to favourable environment for pods/plant, whereas 'VIKAS 35', 'WSP 50', 'RGC 1092', 'RGC 1038', 'RGC 1076', 'HGS 02-1', 'CLBH 201', 'HGS 884', 'GAUG 004', 'GAUG 005', 'RGC 1002' and 'RGC 986' showed more pods/plant, bi < 1 and non-significant s²di

values indicated their better performance and stability in unfavourable environments.

'RGC 1088', 'HG 155-56', 'VIKAS 35', 'HGS 891', 'RGC 1078', 'RGC 1077', 'AVKG 73', 'CAZG 6', 'RGC 1030', 'HGS 880', 'RGM 114', 'RGC 1029', 'GAUG 003', 'GAUG 005' and 'RGC 1002' had more 100-seed weight, bi > 1 and very low s²di values indicated their stability and adaptation to favourable environment while 'HGS 02-29', 'HGS 365', 'WSP 50', 'HGS 02-1', 'CLBH 201' and 'RGC 1059' recorded with more 100-seed weight than population

mean, $b_i < 1$ and very low s^2_{di} values indicated their better performance, high stability and adaptation to unfavourable environments for this trait.

Correlation and path analysis

The analysis of variance showed that the genotypes differ significantly among themselves for all the characters studied indicating the presence of sufficient variability in the material. Positive and highly significant correlation of seed yield/plant was found with pods/plant (0.89), seeds/pod (0.53), secondary branches/plant (0.49), plant height (0.48) and primary branches/plant (0.29) (Table 3). The results are in agreement with the earlier findings in clusterbean (Mahla and Kumar 2006).

Endosperm had highly significant and positive correlation with gum content (0.29) and 100-seed weight (0.20). The association of primary branches was also highly significant and positive (0.76) with secondary branches. Further, significant negative correlation was found between 100-seed weight and plant height, pods/plant, primary and secondary branches/plant, indicating that the taller plant had smaller seeds. The results confirm the findings of Singh *et al.* (2005).

The highest positive and direct effect on seed yield was shown by pods/plant followed by seeds/pod and 100-seed

weight, while direct contribution of very low negative magnitude to it was made by primary branches and gum content (Table 4). This is well reflected from partial R^2 values that out of all the characters only pods/plant (76%) and seeds/pod (15%) contributed seed yield directly. The other three characters, viz plant height, primary branches and secondary branches have contributed via indirect effect. Even though R^2 of 100-seed weight with yield was only 0.12 but it had adequate positive direct effect. Shekhawat and Singhania (2005) observed that pods/plant, branches/plant, clusters/plant, pods/cluster, 100-seed weight and plant height had direct and positive effect on seed yield.

The study concluded that genotypes 'VIKAS 35', 'HGS 891', 'RGC 1038', 'RGC 1077', 'RGC 1055' and 'GAUG 004' were stable and had low response to the change of environment and thus can be suitable for poor environments. However, genotypes 'RGC 1029', 'GAUG 005', 'RGC 1002', 'RCG 986', 'HGS 880', 'CLBH 201', 'CAZG 6', 'CAZG 50', 'GAUG 003', 'RGM 114', 'HGS 884' and 'HGS 02-1' gave high seed yield but these were high responsive to the change of environment showing their adaptation in favourable environments. These genotypes could be utilized in breeding programme for yield improvement in clusterbean. Seed yield was significantly and positively correlated with

Table 3 Correlation matrix for different traits in clusterbean

Character	1	2	3	4	5	6	7	8	9	10
Days to 50% flowering	1.00	0.05	-0.20 **	-0.04	0.11	0.01	0.08	0.11	0.09	0.06
Plant height (cm)		1.00	0.74 **	0.82 **	0.23 **	0.59 **	-0.55 **	-0.12	-0.06	0.48 **
Primary branches/plant			1.00	0.76 **	0.00	0.48 **	-0.60 **	-0.10	0.01	0.29 **
Secondary branches/plant				1.00	0.11	0.64 **	-0.51 **	-0.10	0.03	0.49 **
Seeds/pod					1.00	0.23 **	0.21 **	-0.08	-0.07	0.53 **
Pods/plant						1.00	-0.18 **	-0.04	0.11	0.89 **
100-seed weight (g)							1.00	0.20 **	0.04	0.12
Endosperm (%)								1.00	0.29 **	-0.02
Gum (%)									1.00	0.08
Seed yield/plant (g)										1.00

* $P=0.05$, ** $P=0.01$

Table 4 Path matrix for seed yield/plant in clusterbean

Character	1	2	3	4	5	6	7	8	9	Correlation
Days to 50% flowering	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Plant height (cm)	0.00	0.03	0.02	0.02	0.01	0.02	-0.02	0.00	0.00	0.48**
Primary branches/plant	0.01	-0.02	-0.03	-0.02	0.00	-0.01	0.02	0.00	0.00	0.29**
Secondary branches/plant	0.00	0.02	0.02	0.03	0.00	0.02	-0.02	0.00	0.00	0.49**
Seeds/pod	0.03	0.06	0.00	0.03	0.28	0.06	0.06	-0.02	-0.02	0.53**
Pods/plant	0.00	0.50	0.40	0.54	0.19	0.85	-0.15	-0.04	0.10	0.89**
100-seed weight (g)	0.02	-0.12	-0.14	-0.12	0.05	-0.04	0.23	0.05	0.01	0.12
Endosperm (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02
Gum (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.08
Partial R^2	0.00	0.01	-0.01	0.01	0.15	0.76	0.03	0.00	0.00	

R square = 0.9494; Residual effect = 0.2249

plant height, seeds/pod, pods/plant, primary and secondary branches/plant. Pods/plant, seeds/pod and 100-seed weight showed the maximum positive effect on seed yield/plant. Also, plant height, seeds/pod, gum content, primary and secondary branches had sizeable indirect effect via pods/plant. Thus pods/plant, branch numbers, plant height and 100-seed weight may be considered effective parameters of selection to increase seed yield in clusterbean.

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