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Research Article

Stability and path co-efficient analysis for yield and its components in pigeonpea [*Cajanus cajan* (L.) Millsp.]

Ramesh[1*], S. Muniswamy[1], Yamanura, B. Praveenkumar and Bharatthi[1]
[1] Agricultural Research Station, Aland Road, Kalaburagi-585101 Karnataka, INDIA.
[2] University of Agriculture sciences, krishi nagar, Dharwad - 580005 Karnataka, INDIA.
E-mail: ramesh4913@gmail.com

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Abstract
A study was conducted to examine the stability and path analysis of the twenty advanced genotypes of pigeonpea including check WRP-1, during *kharif*-2012, 2013 and 2014 under irrigated condition at the Agricultural Research Station, Kalaburagi. Pod length (0.378, 1.612), pod bearing length (0.493, 1.043), secondary branches (0.314, 0.935) and number of pods per plant (0.362, 0.539)had the highest positive direct effect on grain yield both at genotypic and phenotypic level. For maximizing the grain yield per plant emphasis should be given in selection of such characters for further improvement in pigeonpea. Highly significant differences among varieties were observed for all the characters except primary branches. The variance due to genotype x environmental (G x E) interaction found to be significant for days to flower initiation, plant height number of seeds per pod and yield per plant. All the traits under the study except for 100 seed weight showed significant differences in different environment. The variance due to pooled deviation was highly significant for all the traits except for primary branches and number of seeds per pod which reflect considerable variability in the material. Out of 20 genotypes studied four entries *viz.*, RVK-285, AKT-9913, JKM-189 and ICP-13579 were consistent and high yielding compared to local check for irrigated conditions.

Key words
Genotype x environment (G x E), pigeonpea, path analysis, stability

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp.] is an important grain legume which occupies a major place in dietary requirement. It belongs to sub-tribe Cajaninae and has diploid genome with 11 pairs of chromosomes (2n = 2x = 22) comprising a genome of 833.1 Mbp (Varshney et al., 2012). India is considered as the native of pigeonpea (Van der Maesen, 1980) because of its natural genetic variability available in the local germplasm and the presence of its wild relatives in the country.

It is cultivated in varied agro climatic conditions ranging from moisture stress and input starved conditions to irrigated conditions. Selection and yield testing are the two major phases of varietal development and the later one is highly influenced by the locations and years of testing. The magnitude of G x E interaction and its components has a direct bearing on the environmental domain of the varieties to be recommended for commercial cultivation. Performance of genotypes in terms of productivity without stability serves no purpose. It is important that the genotypes must not only be productive but also be responsive to increasing fertility status and varied levels of intensities of management of the crop. The magnitude of G x E interaction and its components has a direct bearing on the environmental domain of the varieties to be recommended for commercial cultivation. With this back ground the present study was undertaken under irrigated situation in three locations to identify stable genotypes and direct and indirect effects of pigeonpea for seed yield and its component traits.

Materials and methods

The present experiment material comprised of 20 genotypes of pigeonpea including check WRP-1received from Indian Institute of Pulse Research, Kanpur. The trials were conducted in a Randomized Block Design with two replications in three years *viz*., *kharif*-2012, 2013 and 2014 grown under irrigated condition; two protective irrigations were given at flowering and pod filling stage. The plot size of two rows each with 4m length was followed with spacing of 75 cm between rows and 25 cm between the plants. Observations were recorded on five randomly selected plants in each replication in each environment in respect of 12 different metric characters *viz.*, days to flower initiation, days to 50 per cent flowering, days to 80 per cent pod maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, pod bearing length, number of pods per plant, number of seeds per pod, pod length (cm), 100- seed weight (g) and seed yield per plant. Path coefficient analysis was carried out as per principle given by Dewey and Lu (1959), stability analysis was carried out by using the stability model proposed by Eberhart and Russell (1966).

Results and discussion

The results of genotypic and phenotypic path coefficient analysis for twelve quantitative characters are presented in (Table 1). High rate (between 0.30 to 0.99) of positive direct effects were observed at genotypic and phenotypic level by means of the traits *viz.*, pod length (0.378 and 1.612),pod bearing length (0.493 and 1.043), secondary branches (0.314 and 0.935) and number of pods per plant (0.362 and 0.539). It indicates that, emphasis can be laid on these four characters during selection of genotypes for improvement of yield. The results are in conformity with reports of Baskaran and Muthiah (2007), Chandirakala and Subbaraman (2010) and Bhadru (2011). Even though low rate (0.10 to 0.19) of positive direct effect was observed for plant height (0.142 and 0.003) and primary branches (0.182 and 0.155) at genotypic and phenotypic level, it is also a important trait for yield improvement. The present findings are in agreement with results of Thanki and Sawargaonkar (2010) for pods per plant, Jaggal (2012) for days to 50 % flowering observed direct contribution of branches per plant. Patel and Acharya (2011) obtained high positive direct effects on yield *via* number of pods per plant and low rate of positive direct effects through plant height, branches per plant and 100 seed weight. While days to flower initiation (-0.081) at genotypic level and days to 50% flowering (-0.032), number of seeds per pod (-1.438) and 100 seed weight (-0.674) at phenotypic level had negative direct effect on seed yield and days to maturity (-0.112 and -0.460) registered negative direct effects on yield both at genotypic and phenotypic level, indicating this trait is not the criteria for yield improvement. Bhadru (2011) observed negative direct effect of day's maturity.

In plant breeding, it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield. In other words, residual effect measures the roles of other possible independent variables were not included in the study on the dependent variable. Relatively moderate, positive residual values of R=0.270 and 0.250 was observed at genotypic and phenotypic level respectively. It indicates the moderate unexplained variation and characters included in the present study accounted for most of the variation.

The Mean Sum of Squares (MSS) due to varieties were significant for all the characters except for primary branches (Table 2). Whereas, MSS was significant for environments in respect of all the ten characters except days to maturity and 100 seed weight. The variance due to Genotype x Environmental interaction found significant for the characters like days to flower initiation, plant height number of seeds per pod and yield per plant indicating its major role in the expression of the trait and the performance of the genotypes for seed yield may be predicted across the environment with greater precision (Kuchanur *et al.*, 2008).

Significant Genotype x Environment interaction for seed yield and other traits has also been reported earlier (Manivel *et al.*, 1999). Environmental + (Genotype x Environment) interaction was significant for days to flower initiation, plant height, secondary branch, number of seeds per pod, pod length, number of pods per plant and seed yield per plant. The characters having significant environmental + (Genotype x Environmental) were considered for stability analysis. Hence, a total of seven out of twelve characters were subjected for stability analysis. While genotype x environmental (linear) were significant for all the characters except for primary branches, pod bearing length and pod length indicating the absence of genetic differences among varieties for regression on environmental indices and thus the further predication of genotypes would be difficult for these traits. The magnitude of Genotype x Environment component was greater than non-linear component for all the character indicating its major role in the expression of the trait and the performance of the genotypes for seed yield may be predicted across the environment with great precision (Kuchanur *et al.*, 2008). All the traits under the study except for 100 seed weight showed significant differences in different environment.

The variance due to pooled deviation (non-linear) was highly significant for all the characters except for primary branches and number of seeds per pod which reflect considerable genetic variability in the material. Different measures of stability have been used by various workers earlier, Finlay and Wilkinson (1963) considered linear regression slopes as a measure of stability. Eberhart and Russell (1966) emphasized the need of considering both linear and nonlinear component of Genotype x Environment interaction in judging the stability of genotypes. Later Breese (1969); Samuel *et al.*, (1970); Parodaand Hayes (1971) and Jatasra and Paroda (1978) emphasized that the linear regression could simply be regarded as a measure of response of a particular genotype whereas deviation around the regression line was the most suitable measure of stability. In the present study the stability was assessed by the parameters suggested by Eberhart and Russel (1966).

The term stable genotype has been used for the average performance in all environments. Hence, such a stable variety has a high mean, unit regression and a minimum deviation from regression table 3 shows that the stability parameters for seed yield components. The genotypes RVK-285 (X =42.713, bi=1.22 andS^2di= 5.69), AKT-9913 (X=40.592, bi=1.53 and S^2di = -7.73) and JKM-189 (X =42.580, bi=1.37 and S^2di= 23.5) had high mean, regression value around unity and minimum deviation from regression for the characters seed yield per plant and test weight. Therefore these genotypes had not only better yield but also stable performance across the environments, while JSA-59 and PUSA-2001 are stable for days to maturity and ICP 4575, AKT-9913 and ICP-8840 are stable for days to flower initiation and days to 50% flowering. WhileRVK-285, ICP-13579 and JKM-189 were found to be a stable for number of seeds per pod, primary branches, secondary branches, pod bearing length, plant height, pod length and number of pods per plant across the environments with good stability under irrigated conditions.

From the present study it can be concluded that pod length, pod bearing length, secondary branches, number of pods per plant, primary branches and plant height showed highest positive direct effects on seed yield both at genotypic and phenotypic level. Hence, emphasis should be placed on these characters while breeding for high yield in pigeonpea. The genotypes RVK-285, AKT-9913, JKM-189 and ICP-13579 were found to be a stable for seed yield and test weight across the environments with good stability for irrigated conditions.

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Table 1. Direct and indirect effects of quantitative characters on seed yield per plant at genotypic and phenotypic level

Characters		Days to flower initiation	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches	Secondary Branches	Pod bearing length (cm)	Number of seeds /pod	Pod length (cm	No. of pods /plant	100 seed weight (g)
Days to flower initiation	G	**-0.081**	0.227	-0.100	0.076	0.067	0.007	-0.124	0.022	-0.032	0.114	0.100
	P	**0.714**	-0.029	-0.413	0.002	0.073	0.484	-0.291	-0.471	0.698	-0.171	-0.297
Days to 50% flowering	G	-0.072	**0.256**	-0.099	0.089	0.085	0.009	-0.119	0.018	-0.027	0.179	0.067
	P	0.637	**-0.032**	-0.408	0.002	0.098	0.676	-0.304	-0.374	0.594	-0.275	-0.196
Days to maturity	G	-0.072	0.226	**-0.112**	0.099	0.076	0.008	-0.027	0.015	-0.025	0.173	0.070
	P	0.641	-0.028	**-0.460**	0.002	0.089	0.604	-0.085	-0.344	0.515	-0.268	-0.204
Plant height (cm	G	-0.043	0.160	-0.078	**0.142**	0.068	0.007	0.132	0.025	-0.037	0.170	0.078
	P	0.398	-0.021	-0.335	**0.003**	0.065	0.475	0.292	-0.581	0.822	-0.260	-0.234
Primary branches	G	-0.029	0.119	-0.047	0.053	**0.182**	0.008	-0.050	-0.024	0.012	0.256	-0.002
	P	0.335	-0.020	-0.266	0.001	**0.155**	0.596	-0.021	0.449	-0.153	-0.463	-0.013
Secondary Branches	G	-0.037	0.160	-0.061	0.069	0.105	**0.314**	-0.059	-0.001	-0.007	0.262	0.046
	P	0.369	-0.023	-0.297	0.002	0.099	**0.935**	-0.267	0.051	0.237	-0.445	-0.142
Pod bearing length (cm)	G	0.020	-0.062	0.006	0.038	-0.018	-0.002	**0.493**	0.011	-0.008	0.062	-0.007
	P	-0.199	0.009	0.038	0.001	-0.003	-0.240	**1.043**	-0.162	0.169	-0.115	0.038
Number of seeds /pod	G	-0.021	0.054	-0.021	0.043	-0.053	0.000	0.063	**0.083**	-0.063	-0.055	0.067
	P	0.234	-0.008	-0.110	0.001	-0.048	-0.033	0.117	**-1.438**	1.626	0.101	-0.269
Pod length (cm)	G	-0.032	0.089	-0.035	0.068	-0.027	0.001	0.049	0.067	**0.378**	-0.050	0.135
	P	0.309	-0.012	-0.147	0.002	-0.015	0.138	0.109	-1.451	**1.612**	0.081	-0.433
Number of pods/plant	G	-0.025	0.127	-0.053	0.067	0.129	0.010	0.085	-0.013	0.011	**0.362**	-0.037
	P	0.226	-0.016	-0.229	0.002	0.133	0.772	0.222	0.269	-0.243	**0.539**	0.111
100 seed weight (g)	G	-0.035	0.075	-0.034	0.048	-0.001	0.003	-0.016	0.024	-0.046	-0.059	**0.229**
	P	0.315	-0.009	-0.140	0.001	0.003	0.197	-0.059	-0.575	1.037	0.089	**-0.674**

Genotypic Residual = 0.270 Phenotypic Residual = 0.250

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Table 2. Pooled MSS values for different quantitative traits over three environments

Traits	Varieties	Env + (Var x Env)	Environments	Varieties x Environment	Environment.(Lin)	Varieties x Environment.(Lin)	Pooled deviation
Days to flower initiation	365.45**	176.60**	1323.82**	116.24**	2647.65**	194.48**	36.06**
Days to 50 % flowering	354.82**	128.67	463.47**	111.05	926.94**	152.42*	66.20**
Days to 80% pod maturity	282.55**	74.27	112.54	72.25	225.09*	101.88*	40.49**
Plant height (cm)	523.30**	1590.08**	27489.13**	226.97*	54978.27**	337.49**	110.63**
Primary branches	4.92	3.6	24.151**	2.5	48.30**	2.58	2.31
Secondary branches	9.10**	8.17**	111.76**	2.71	223.52**	3.67*	1.67**
Pod bearing length (cm)	121.12*	58.02	115.35	55.01	230.71*	57.12	50.25**
Number of seeds per pod	0.18**	0.49**	8.52**	0.074**	17.05**	0.126**	0.022
Pod length (cm)	.356*	0.97**	16.44**	0.162	32.89**	0.176	0.140**
Number of pods per plant	2053.65**	1840.25**	8497.39**	1489.88**	16994.80**	2408.8**	542.41**
Yield per plant (gm)	175.66**	165.91**	2189.04**	59.42*	4378.088**	90.45**	26.97**
100 seed weight	9.49**	0.79	0.6	0.8	1.2	1.16*	0.43**

*, ** significant at 5 and 1 per cent level respectively

Table 3. Mean and stability parameters in 20 genotypes of pigeon pea

Traits / Genotypes	Days to flower initiation			Days to 50% flowering			Days to maturity			Plant height (cm)		
	Mean	**bi**	**S2di**	**Mean**	**bi**	**S2di**	**Mean**	**bi**	**S2di**	**Mean**	**bi**	**S2di**
PUSA2001	73.00	1.28	46.12	79.66	1.53	44.39	138.50	4.76	-2.95	115.83	0.86	-4.81
JKM189	96.83	1.57	4.91	107.17	1.88	3.34	156.83	-1.00	-1.95	140.78	1.75	-8.05
BDN-2008-1	96.00	1.69	25.83	104.50	1.75	23.72	155.66	-1.98	128.05	131.77	1.33	-10.72
JKM-7	108.66	0.93	20.27	116.66	1.70	14.11	169.33	-0.47	25.82	144.05	1.62	17.44
WRP-1	84.00	2.09	2.13	89.50	3.40	51.70	147.50	-0.59	23.67	102.38	0.73	638.37
ICP 11477	82.12	-0.52	2.34	91.33	1.88	11.09	143.50	7.29	59.43	125.25	0.71	2.97
ICP 13579	111.33	1.00	210.46	119.16	1.10	298.89	166.83	0.37	5.71	131.27	0.76	-18.01
ICP 995	95.17	1.59	6.85	104.50	1.90	65.15	156.00	-0.65	31.79	131.67	1.01	-16.20
ICP 4575	93.00	1.65	-2.25	100.00	2.13	-3.10	151.00	-2.03	14.45	117.77	1.23	-12.53
ICP 14471	77.83	2.06	67.24	87.16	4.17	8.41	150.67	-0.86	100.90	120.33	1.31	-0.64
AKT 9913	92.16	0.78	-2.73	102.00	0.36	-2.72	154.66	2.85	121.10	133.55	1.06	37.45
ICP 348	95.50	1.16	9.29	104.50	1.03	11.60	161.16	1.42	8.49	113.72	1.18	0.71
ICP 7366	82.66	-0.03	3.26	92.16	-1.21	10.39	138.33	2.93	87.71	103.27	0.68	16.91
ICP 8840	102.00	1.46	-2.45	111.66	1.56	-3.15	166.83	-0.46	8.93	135.77	0.73	115.58
RVK 275	109.66	-1.73	112.24	115.16	-2.82	325.18	165.33	4.86	5.00	147.33	0.56	317.14
BENNUR LOCAL	85.83	-0.06	-2.03	92.50	-0.37	-0.01	142.16	4.22	4.76	120.44	1.00	-5.84
RVK 285	99.00	0.80	20.01	100.16	1.45	226.13	161.83	-2.49	3.39	150.00	1.36	-13.54
BDN 2008-12	93.33	-1.21	30.07	99.33	-1.73	28.62	147.00	4.96	-3.17	128.00	0.54	35.26
JSA 59	110.83	2.16	33.56	116.75	3.11	134.74	164.50	-3.72	113.99	132.88	62.00	152.51
BDN 711	89.17	3.33	80.41	106.16	0.95	12.26	150.75	0.59	-2.96	121.47	0.96	600.37
Population mean	**93.908**			**102.004**			**154.396**			**127.38**		

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Table 3. Contd.,

Traits / Genotypes	Primary branches			Secondary Branches			Pod bearing length (cm)			Number of seeds /pod		
	Mean	**bi**	**S2di**	**Mean**	**bi**	**S2di**	**Mean**	**bi**	**S2di**	**Mean**	**bi**	**S2di**
PUSA2001	7.61	0.20	-0.94	1.07	0.12	1.03	30.332	1.63	10.05	4.66	1.77	-0.06
JKM189	10.77	2.83	6.02	4.95	1.56	-0.34	36.75	6.08	-12.68	4.25	0.89	-0.06
BDN-2008-1	10.16	1.24	9.25	3.11	1.42	-0.61	38.58	2.31	-11.11	4.8	0.59	-0.05
JKM-7	9.35	2.31	-1.41	3.26	1.38	0.18	31.89	1.93	-13.84	4.57	1.09	-0.02
WRP-1	8.72	0.02	-1.29	0.54	-0.15	-0.36	39.71	0.02	130.21	4.22	0.59	-0.06
ICP 11477	7.34	1.93	-1.39	3.84	1.62	4.93	37.05	-2.52	58.49	4.25	1.1	0.01
ICP 13579	10.33	0.53	0.79	6.58	1.46	6.31	28.15	0.54	45.22	4.61	1.19	-0.02
ICP 995	10.39	1.71	0.79	4.89	0.90	0.09	26.69	2.62	58.66	4.3	1.02	-0.04
ICP 4575	10.72	1.65	-1.22	2.65	0.53	-0.47	21.94	1.99	-13.14	3.778	1.41	0.03
ICP 14471	8.81	0.91	-0.07	3.52	0.87	1.32	33.88	0.76	55.28	4.27	0.95	-0.04
AKT 9913	10.84	-0.70	9.15	6.11	1.04	-0.45	40	2.15	28.2	4.18	0.71	-0.04
ICP 348	10.55	-0.24	-1.20	6.50	1.15	-0.42	24.33	3.29	-9.42	4.03	0.75	-0.04
ICP 7366	8.72	-0.63	1.87	2.27	0.17	0.20	26.338	2.25	9.55	4.138	1.03	-0.04
ICP 8840	10.95	1.82	-0.37	6.05	2.08	0.47	35.002	2.09	172.73	4.32	0.85	-0.06
RVK 275	12.33	1.18	1.95	5.64	1.40	-0.60	30.55	0.56	-6.66	4.3	0.59	-0.05
BENNUR LOCAL	11.44	2.09	-0.85	5.26	1.22	1.86	32.302	-3.03	-13.52	4.25	0.66	-0.06
RVK 285	9.11	2.13	-1.14	3.94	1.08	2.83	41.33	1.39	20.33	4.49	0.88	-0.02
BDN 2008-12	9.39	0.29	0.06	4.47	1.03	0.12	36.02	-3.27	43.57	4.37	0.56	-0.06
JSA 59	9.28	0.28	-1.36	6.04	0.26	-0.31	20.72	-0.36	135.45	4.58	1.55	-0.06
BDN 711	8.67	0.45	-0.35	4.42	0.86	6.32	23.58	-0.42	30.48	4.68	1.83	-0.06
Population mean	**9.77**			**4.26**			**31.76**					

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Table 3. Contd.,

Traits / Genotypes	Pod length (cm)			Number of pods/plant			Seed yield per plant(g)			100 seed weight (g)		
	Mean	**bi**	**S2di**	**Mean**	**bi**	**S2di**	**Mean**	**bi**	**S2di**	**Mean**	**bi**	**S2di**
PUSA2001	4.91	1.16	0.08	78.27	-0.16	977.71	19.23	0.16	3.11	9.53	1.48	0.35
JKM189	4.56	0.91	0.03	158.22	4.46	2652.4	42.58	1.37	23.59	10.66	6.97	0.03
BDN-2008-1	5.33	1.63	-0.04	129.77	2.34	-110.66	35.15	1.38	90.34	9.53	1.03	0.85
JKM-7	4.69	1.11	0.52	130.42	2.59	1020.16	33.92	0.32	3.10	9.44	-2.67	1.22
WRP-1	4.36	1.25	0.21	93.94	-0.41	514.56	35.89	1.09	-5.87	9.92	1.53	-0.09
ICP 11477	4.45	1.01	0.23	107.11	1.75	-17.03	29.37	0.55	92.74	8.30	-10.27	0.92
ICP 13579	4.83	1.03	0.07	163.00	2.33	-39.09	34.42	1.30	-4.90	8.23	2.23	0.08
ICP 995	4.47	0.94	-0.04	148.72	2.01	352.81	35.20	0.69	-9.65	8.07	2.54	-0.09
ICP 4575	4.06	0.42	0.01	109.61	0.75	-67.04	20.20	0.50	-4.87	8.13	2.59	0.2
ICP 14471	4.38	1.13	0.11	117.88	1.81	88.12	29.01	1.07	-6.66	8.95	-2.12	-0.11
AKT 9913	4.60	1.40	-0.04	165.77	-0.17	-71.22	40.59	1.53	-7.73	10.04	4.87	..49
ICP 348	4.13	1.07	0.00	156.61	3.09	57.99	32.80	1.67	-9.85	8.34	-1.89	1.56
ICP 7366	4.24	0.53	-0.01	113.61	-2.72	14.15	18.99	-0.53	0.72	8.04	-6.57	0.45
ICP 8840	4.55	0.54	-0.04	159.50	0.16	-35.82	37.12	1.67	31.61	9.49	2.95	0.28
RVK 275	4.75	0.99	0.37	146.44	0.57	2407.16	43.71	1.92	114.47	10.06	3.84	-0.01
BENNUR LOCAL	4.38	0.65	0.03	162.16	0.82	425.36	40.14	1.83	19.35	10.00	1.92	0.12
RVK 285	4.90	1.13	0.29	136.33	1.25	636.98	42.17	1.22	5.69	11.42	3.88	-0.11
BDN 2008-12	4.68	0.71	0.02	133.66	0.13	-90.63	41.67	1.02	14.55	9.12	7.4	-0.08
JSA 59	5.33	1.56	0.12	100.11	-1.96	-25.34	28.37	0.21	-6.56	16.10	4.16	0.17
BDN 711	4.87	0.82	0.01	111.16	1.35	-61.25	32.95	1.03	-2.21	9.60	-3.87	0.16
Population mean	**4.62**			**131.11**			**33.70**			**9.65**		