Stability Analysis for Yield and its Components under Different Environmental Conditions in Pea (*Pisum sativum* L.)

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Thirty five indigenous and exotic genotypes of pea were evaluated under eight environments for stability analysis for seed yield and its components using Eberhart and Russel's (1966) model. Pooled analysis of variance for all thirteen characters indicated high differences among the genotypes and environments. The linear component was observed to be significant for all the characters suggesting that the prediction of performance of genotypes was possible across environments. Genotypes EC 341995, NIC 11249, BDJ 42-174, DMR-11 and EC 381864 were observed to be stable and high yielding under favourable conditions while genotype DMR-1 would perform better in adverse environmental conditions and thus could be utilized as donor parent to breed higher yielding line for poor environment.

Key words: *Pisum sativum*, stability, indigenous, exotic, adaptability

Stability in performance is one of the most desirable properties of a genotype for selecting as parent for any breeding programme to develop a variety suitable for wide cultivation. It is well known that different genotypes varying in their response to a series of environments are called stable. The study of G x E interaction is very important in evaluating the range of adaptability of breeding material. Sometimes the uni-location trials can also serve the purpose, provided different environments are created by planting experimental material at different dates of sowing, using various spacing and doses of fertilizers and irrigation level etc. (Luthra *et al.* 1974). With respect to fitness for agricultural purposes, specially for yield, the varieties adjusting their phenotypic state in response to change in environment so that they are able to give their near maximum economic returns are called "well buffered" varieties (Allard and Hansche, 1964). It is in this context that the present investigation was carried out to assess the stability of 35 genotypes of pea under varying environments.

Materials and Methods

The present investigation was undertaken during 1996-97 and 1997-98. The experimental material comprised of 35 exotic and indigenous genotypes including some released varieties (Table 2). The material was grown in a Randomized Block Design with three replications under eight environments which were created by using different date of sowing (10-15 November, 25-30 December) and fertility doses (N:P 20:40 and N:P 10:40). Each entry was sown in two rows, each 3 m long, and the plants were placed at 45 x 15 cm. The research trials were conducted at Kisan Post Graduate College, Simbhaoli, Ghaziabad, U.P. The observations were recorded on five randomly selected plants in each plot for seed yield and related attributes and data were subjected to stability analysis as per Eberhart and Russells (1966) model.

Results

The pooled analysis of variance for genotype and environment was highly significant for all the thirteen characters, thus indicating the presence of genetic variability in the material studied and variation in the environments under study. Ram Niwas *et al.* (1993) and Gupta *et al.* (1998) reported highly significant variance amongst the genotypes and environments for all characters studied. Muhammad *et al.* (2001) studied 11 genotypes during *rabi* 1999-98 and observed that all the parameters under study were statistically significant. The analysis of variance (Table 1) exhibited that the linear component of environment was significant for all the characters. The G x E interaction was significant for number of pods per plant, dry matter yield and seed yield per plant. The linear component of G x E was also significant for days to flowering, number of pods, number of seeds per pods, The pooled deviation observed was highly significant for all the characters. The variances due to deviation (Non-linear) were significant for all the traits reflecting considerable genetic diversity in the genotypes as has been reported earlier by Perkins and Jinks (1968). Such non-linear deviation might also be of practical

Table 1. Analysis of variance for seed yield and its components in pea.

Source	d.f.	Days to flowering	Days to green pod harvesting	Days to maturity	Plant height (cm)	No. of branches/ plant	No. of pods/ plant	Pod length (cm)	No. of pods/ node	Dry matter yield/ plaint (g)	No. of seeds/ pod	Seed yield/ plant (g)	Harvest index	100 seed weight (g)
Genotype (G)	34	86.82**	89.11**	68.53**	5764.01**	0.92**	45.74**	3.14**	0.48**	563.18**	2.31**	66.73**	169.10**	55.68**
Environment (E)	7	966.22**	1966.22**	3795.71**	10082.37**	15.02**	1530.29**	2.98**	1.24**	9055.76**	15.76**	1722.53**	2774.97**	43.08**
G X E	238	16.68	15.99	12.94	492.20	0.23	19.83**	0.21	0.08	191.40**	0.40	24.16**	80.99	4.52
E (Linear)	1	6763.61**	13762.44**	26569.09**	70575.78**	105.16**	10712.05**	20.85**	8.66**	63390.41**	110.32**	12057.74**	19424.80**	301.56**
G X E (Linear)	34	28.17**	25.66**	16.81	546.49	0.28	58.33**	0.23	0.11*	651.63**	0.67**	87.78**	118.69*	7.85**
Pooled deviation	210	14.31**	13.97**	11.94**	469.34**	0.22**	13.03**	0.20**	0.07**	111.42**	0.34**	13.17**	72.58**	3.85**
Pooled error	544	4.35	17.00	5.02	321.53	0.37	20.56	0.27	0.10	113.54	0.43	19.54	71.64	0.44

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

value to construct and test the utility of the multiple regression models more critically along with the complex mechanism of adaptation. Pan *et al.* (2001) observed that non-linear components of (G x E) interaction were high and low respectively for green pod yield.

Each genotype exhibited different stability (Table 2) for all the attributes with respect to regression coefficient (b) and deviation from regression (S^2d_i). Considering the response of genotypes to environmental changes, the variety Arkel showed early maturity with b<1 and significant S^2d_i while genotype NIC 18727 was observed to be stable with unit "b" and non significant S^2d_i. The variety HFP 4 which showed minimum plant height was stable having b<1 and non significant S^2d_i. The genotypes PLP 359, EC 341995, NIC 12860, NIC 18735 and NIC 18727 were stable for pods per plant with high mean value and non-significant S^2d_i. For pod length Arkel, Bonneville, HUDP-6 and JM 1 were observed to be stable with high mean performance which was comparable to population means, unit 'bi' and S^2d_i = 0. In general, non-linear components of G x E were present for pod length whereas it was reverse in the case of seed per pod. For grain yield per plant genotypes BDJ 42-174, NIC 11249, DMR 11, Boneville, PLP-359, Arkel, Rachna, DDR 12 and EC 381864 were observed stable as they showed higher mean performance, unit regression and S^2d_i = 0. Among these genotypes only Rachna may be cultivated under normal environment conditions while other genotypes needed better management practices for better expression of yield and related traits. Pan *et al.* (2001) have also observed that the variety Boneville was a good performer and stable for green seed weight and suitable for favourable environments.

Genotypes KPR 103, HUDP 8 and LFP 96 for number of pods per plant; KPFD 59, NIC 11249, EC 381856 for number of seeds per pod and HUDP 8, EC 381856 and NIC 11191 for grain yield showed below mean performance, unit regression coefficient and non-significant S^2d_i. This indicated that the performance of these genotypes can be improved by adopting suitable management practices and can also be used as one of the parent along with high mean performance to breed genotypes with high mean performance and wider adaptation.

Genotypes DDR 12, Bonneville, KPFD 59, Rachna and Arkel had significantly higher yield than rest of the genotypes and also exhibited unit (b = 1) regression

Table 2. Estimation of mean and stability parameters for thirteen characters in 35 genotypes of pea

Genotypes	Days to flower			Days to green pod harvest			Days to maturity			Plant height (cm)			No. of branches/plant			No. of pods/plant		
	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i
DDR-13	74.21	0.74	-0.36	97.92	0.66	4.06	115.79	0.81	26.50*	69.10	0.66	283.73	2.80	0.75	0.41	9.26	0.87	11.10
KPF-103	76.29	0.74	0.86	98.42	0.71	11.71	117.33	0.81	9.87	102.41	0.54	-8.81	2.35	0.66	0.06	8.25	0.72	0.90
HUDP-8	76.00	1.12	3.59	100.42	0.83	-3.88	118.88	0.82	7.09	67.52	0.62	-64.94	2.38	0.71	0.17	6.99	0.59*	0.56
Arka Ajeet	73.38	0.82	-0.39	94.92	0.40	14.93	114.29	0.61*	9.14	76.21	0.41	133.86	2.38	0.69	0.05	9.32	0.49*	4.19
DMR-1	77.37	0.87	0.55	101.42	0.95	-0.13	119.42	1.04	1.13	111.98	1.13	329.25	2.92	0.85	0.22	10.75	0.61	-0.51
DDR-12	73.46	1.02	8.38	98.96	0.84	-4.48	116.96	0.81	19.24	70.00	-0.05*	-36.57	2.55	0.76	0.03	11.57	1.13	4.21
Boneville	72.50	0.71	17.91*	99.21	1.26	-4.48	117.21	1.04	5.01	79.43	0.91	83.90	2.39	0.36	0.07	12.35	0.62	-3.42
KPFD-59	73.25	1.56*	12.64	104.92	1.12	-2.81	122.21	1.13	2.94	99.96	1.22	-2.29	2.57	1.11	0.02	9.69	0.97	-1.20
Rachna	77.08	1.02	5.46	102.54	1.05	-3.60	121.08	1.09	2.07	136.62	2.02	166.89	2.94	1.18	-0.02	11.68	0.78	5.24
NIC 23636	77.29	1.27	0.15	101.29	1.23	-1.20	118.79	1.08	4.71	114.67	1.32	319.10	3.08	1.02	0.19	12.21	0.83	15.24
HUDP-6	75.54	1.27	1.16	100.33	1.07	-3.62	118.48	1.09	5.63	75.20	0.77	-24.17	2.90	1.15	0.00	9.21	0.83	-5.35
JM-1	73.38	0.91	4.21	99.96	1.11	-2.60	117.12	1.03	2.79	71.49	0.25	146.55	2.48	0.78	-0.07	10.89	0.82	-5.14
Arkel	66.92	0.81	37.63*	88.92	0.50*	22.44	109.08	0.84	7.19	61.65	0.78	-51.23	2.34	1.05	-0.05	12.21	0.95	10.10
LEP-96	83.38	1.42	3.98	107.88	1.18	3.16	121.67	0.94	3.73	54.37	0.56	-85.69	2.83	0.99	0.11	8.32	0.76	-5.23
DMR-11	74.79	1.03	0.03	99.67	1.05	-4.31	118.67	0.97	5.04	124.04	1.84	306.52	3.43	1.46	-0.01	14.90	1.70*	-0.79
HFP-4	81.88	1.47	5.95	105.38	1.36	-3.47	112.12	1.16	0.35	46.71	0.55	-91.08	2.83	1.07	-0.05	11.63	1.45*	-4.10
KPMR-144-1	78.37	0.16	99.80*	100.96	1.00	38.17	118.54	0.39	27.20*	49.22	0.53	-32.78	2.23	0.92	-0.03	10.53	0.95	-2.16
EC381864	74.88	1.03	1.03	99.62	0.92	-3.90	119.87	1.03	3.99	56.03	0.49	-90.24	2.40	1.11	0.03	11.49	1.26	12.74
BDJ-42-174	78.33	-0.01*	77.51*	99.00	0.88	49.65	119.67	1.01	49.95	124.33	1.74	554.98	3.13	1.60*	0.15	18.03	2.44*	7.67
NIC11249	78.00	1.16	66.69*	101.71	1.17	-1.50	121.12	1.07	1.83	78.10	1.71	1971.57*	2.98	1.63*	1.04	15.99	1.92*	24.23
PLP-359	76.04	1.27	3.22	102.13	1.41*	-3.42	120.08	1.25	7.97	133.04	1.37	826.95	3.81	1.18	0.22	13.49	1.11	8.62
EC381865	73.88	0.11*	8.25	103.88	1.05	137-85*	117.83	0.91	9.45	70.43	1.12	328.98	2.50	1.51	0.01	11.14	1.42*	-1.74
EC341766	73.12	1.17	10.79	97.87	0.86	3.64	116.29	0.98	9.70	96.64	1.68	-6.56	2.73	1.00	0.02	12.28	1.10	-2.34
EC27166	71.83	1.03	2.13	96.25	1.08	6.93	113.79	1.24	19.88*	90.16	0.26	46.56	2.78	0.92	-0.01	9.96	0.35*	-0.16
EC341995	75.38	0.67	22.34*	102.67	1.08	-1.80	120.50	0.98	6.38	74.44	1.53	2198.99*	2.78	1.29	0.05	15.85	1.30	12.68
EC341787	78.17	1.73	6.74	101.87	1.55*	0.94	121.12	1.25	3.05	130.85	1.22	1611.03	3.15	1.19	0.26	11.36	0.83	5.00
KNM-4	77.79	1.17	-0.06	101.67	1.08	-2.53	118.67	0.99	6.17	69.18	0.81	779.84	2.85	1.10	-0.05	11.85	1.06	10.60
NIC23625	77.67	1.21	1.55	101.04	0.92	-1.03	119.75	1.03	0.34	119.84	1.54	70.96	2.75	1.09	0.01	10.75	0.97	8.39
NIC12860	78.33	1.32	4.67	102.58	1.40	-2.17	120.21	1.22	11.77	110.30	1.13	11.89	2.57	0.51	0.02	9.32	0.60	9.00
NIC11181	73.25	0.93	2.58	99.17	1.10	-3.60	118.83	0.97	2.58	11.21	0.65	1241.65	2.76	0.88	-0.03	13.03	1.00	5.09
EC381856	73.08	0.62	9.35	99.62	0.70	2.20	117.79	0.83	9.05	54.75	0.71	178.30	2.24	0.65	-0.05	9.41	0.44*	-1.66
NIC11191	74.50	1.06	-0.16	65.17	1.14	11.78	111.71	1.15	23.87*	66.75	1.31	407.24	3.11	0.43	0.21	9.11	0.54*	-2.44
NIC18735	75.87	1.21	2.94	99.50	0.67	-0.21	118.54	0.95	7.39	122.75	1.54	860.58	2.76	0.99	0.06	13.56	1.10	33.10
NIC18727	71.21	1.06	1.29	93.29	0.98	10.70	113.54	1.12	21.99*	98.91	1.47	169.94	2.75	1.11	0.24	13.93	0.93	48.53
EC8495	76.25	1.34	28.95	98.96	0.72	31.92	119.71	0.84	29.69*	105.42	0.65	240.97	2.83	1.28	0.08	13.26	1.56*	15.33
Population mean	75.79			99.89			118.19			89.25			2.75			11.53		

(contd.)

Table 2 contd.

Genotypes	Pod length (cm)			No. of pods/node			Dry matter yield (g)			No. of seeds/pod			Seed yield/plant (g)			Harvest index			100 seed weight (g)		
	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i	Mean	b_i	s^2d_i
DDR-13	5.76	0.90	0.18	1.82	0.47	-0.02	20.38	0.50*	21.27	4.03	0.27*	0.43	7.73	0.77	17.95	33.90	1.94*	20.39	18.66	2.08	3.30*
KPF-103	5.41	-0.35	0.22	1.44	2.11*	0.00	21.28	0.53	35.88	4.30	-0.18	0.04	6.55	0.53*	4.71	30.65	1.50	78.03	19.22	1.19	3.30*
HUDP-8	5.86	1.06	0.22	1.47	1.58	-0.02	17.45	0.63	-22.72	4.65	0.88	0.60	5.28	0.56	4.00	28.17	0.57	29.17	14.69	1.14	1.67
Arka Ajeet	6.12	0.95	0.01	1.82	0.55	0.02	20.87	0.33*	-18.54	4.69	0.34*	0.16	7.77	0.49*	7.84	33.99	0.93	26.45	17.30	0.93	3.82*
DMR-1	5.81	0.61	0.00	1.67	1.47	0.05	33.62	1.05	5.42	4.95	0.54	-0.04	9.66	0.61*	-0.02	31.44	0.74	117.75	18.61	0.65	1.70
DDR-12	5.91	1.27	0.10	1.85	0.87	0.03	27.12	0.89	19.29	4.84	0.59	0.03	11.01	1.31	20.02	35.95	1.31	-7.71	18.43	2.03	1.84*
Boneville	6.65	1.23	0.13	1.93	0.06	-0.01	29.09	0.64	-27.94	5.91	1.59	0.04	12.48	1.10	-1.60	40.54	1.41	12.28	16.13	0.71	2.01*
KPFD-59	5.76	0.85	-0.02	1.76	1.38	0.05	26.65	0.70	4.80	3.83	1.19	-0.05	7.08	0.91	-4.80	26.29	1.76*	-16.61	17.28	1.22	1.94*
Rachna	5.98	0.86	0.02	1.37	0.75	0.11	37.73	1.06	46.56	4.51	0.62	-0.03	10.34	0.86	-1.08	29.17	1.09	43.64	20.20	1.73	2.76*
NIC 23636	5.42	0.71	0.05	1.51	0.58	0.13	28.22	0.83	55.76	4.55	0.78	0.15	8.69	0.72	7.93	21.10	1.00	26.08	15.04	0.70	3.25*
HUDP-6	6.45	1.23	0.04	1.65	1.09	0.06	25.31	0.95	-19.62	5.02	1.87*	0.11	7.84	0.90	-4.70	30.31	0.71	28.44	15.95	0.82	1.27
JM-1	6.32	1.55	0.05	1.70	0.51	0.01	25.58	0.89	-20.97	5.25	1.12	0.75	8.80	0.75	-1.17	32.50	0.62	77.13	14.55	0.61	1.44
Arkel	7.20	2.93	0.04	1.95	0.42	0.02	23.68	0.90	-27.53	5.88	1.02	0.33	10.48	1.11	6.30	41.30	0.64	8.22	13.59	1.25	0.89
LEP-96	5.73	0.36	-0.01	1.88	0.74	0.02	23.42	0.81	-3.33	5.00	1.42	0.91	6.49	0.70	-5.21	25.75	0.86	17.07	14.29	1.25	6.76*
DMR-11	5.59	0.29	0.10	1.46	2.03*	0.02	43.32	2.01*	81.30	4.42	0.39*	0.25	12.64	1.51*	-3.36	30.72	0.83	17.83	18.88	1.55	2.27*
HFP-4	5.49	1.78	0.04	1.82	0.86	0.04	24.90	1.17	-12.60	4.23	1.22	0.33	9.60	1.55*	-4.34	33.39	1.88*	21.04	16.10	2.75*	1.58
KPMR-144-1	5.59	1.22	0.18	1.99	0.06	0.03	20.64	0.88	-9.70	4.03	1.15	-0.10	8.53	1.03	-0.86	38.49	0.75	17.90	17.85	1.88	0.39
EC381864	6.13	1.27	0.10	1.70	0.74	0.11	26.17	1.21	-29.70	4.94	1.60	0.02	11.53	1.58*	12.24	39.72	0.66	68.11	18.35	0.00	1.73
BDJ-42-174	6.26	1.70	-0.03	1.88	0.35	0.00	53.65	3.15*	507.15*	5.04	1.09	-0.10	19.81	2.96	26.70	33.50	0.80	-7.05	20.06	1.51	1.35
NIC11249	5.26	0.76	0.10	1.92	0.48	-0.01	38.94	2.19*	711.81*	3.72	1.54	0.30	12.87	1.81*	4.60	32.86	1.03	100.48	19.76	-0.72	11.28*
PLP-359	5.37	1.87	0.07	1.39	2.07*	0.03	48.08	2.11*	209.37	4.75	1.58	0.19	9.39	1.04	-1.58	24.03	1.02	84.71	14.50	0.17	0.07
EC381865	5.56	0.72	0.74	1.76	0.80	0.07	28.26	1.54	58.50	5.09	1.13	0.52	9.20	1.19	-4.75	31.04	0.72	14.51	15.66	-0.59	2.15*
EC341766	4.60	0.73	0.00	1.25	1.09	0.09	21.18	0.70	0.55	4.33	1.21	0.01	7.20	0.85	-4.19	30.62	0.69	123.81	13.33	0.37	3.83*
EC27166	4.97	0.64	0.04	1.17	0.69	0.10	20.88	0.61	-8.68	4.56	0.90	0.09	6.87	0.47*	1.64	31.61	0.23*	15.22	14.74	0.41	3.57*
EC341995	5.87	0.82	0.00	1.95	0.27	-0.02	31.30	1.60*	120.61	5.09	1.65	0.16	11.88	1.48*	7.54	36.87	0.16*	67.27	13.06	1.45	1.08
EC341787	5.29	1.17	0.13	1.40	1.31	0.06	32.62	0.95	176.31	4.55	1.10	0.15	8.36	0.88	1.36	29.99	1.33	277.50	14.70	1.64	3.59*
KNM-4	5.80	1.07	-0.04	1.91	0.52	-0.02	26.48	0.97	65.86	4.82	1.18	-0.02	9.79	1.19	4.91	35.19	1.40	8.62	16.61	1.11	0.04
NIC23625	5.65	0.52	0.10	1.55	2.47*	0.01	30.29	0.98	-27.08	4.75	1.47	0.22	7.42	0.74	15.18	23.46	0.81	74.17	15.27	0.22*	4.46*
NIC12860	4.97	0.52	0.09	1.40	1.29	0.10	26.06	0.68	37.11	4.05	0.88	0.53	6.63	0.69	11.05	24.83	1.71	9.31	16.41	0.95	2.49*
NIC11181	5.35	0.82	-0.03	1.49	2.01	-0.01	25.35	0.60	-28.39	4.35	0.54	0.10	9.17	1.00	0.30	32.94	1.22	91.40	16.35	1.95	0.92
EC381856	5.16	-0.09*	0.41	1.71	-0.26	0.13	17.14	0.33*	-26.39	3.42	0.85	0.13	4.92	0.12*	-2.72	28.72	0.34	98.89	15.83	-1.24	16.69*
NIC11191	3.73	2.44*	0.52	1.19	0.80	0.06	14.18	0.35*	120.10	4.51	0.92	0.41	3.18	0.46*	2.51	23.94	0.93	55.42	6.59	3.46*	23.25*
NIC18735	5.16	0.98	0.00	1.31	1.40	0.08	29.71	0.49	215.97*	4.28	1.09	0.30	9.16	0.74	25.18	31.49	1.70	-12.14	15.38	-0.01*	2.49*
NIC18727	4.74	0.85	0.40	1.29	1.92	0.05	26.56	1.21	254.85*	4.90	1.09	0.02	9.91	1.22	74.02	32.62	0.50	40.72	12.49	1.58	5.41*
EC8495	5.31	0.66	0.08	1.60	1.83	0.01	29.31	0.60	109.70	4.04	0.33*	0.03	9.06	1.19	18.16	27.23	1.73	76.93	15.48	1.24	5.01*
Population mean	5.61			1.63			27.87			4.61			9.17			31.50			16.04		

b_i – Regression coefficient; S^2d_i – Deviation coefficient and non-significant deviation from regression ($S^2d_i = 0$). Thus these genotypes could be termed as high yielding, highly stable and could be recommended for general cultivation. Out of these 5 genotypes DDR 12, Boneville and Arkel showed earliness for flowering and maturity and had the lower values than the population mean. For pods per plant the mean values were higher over population mean for Boneville, Rachna and Arkel. The genotypes DDR 12, Boneville, KPFD 59 and Arkel have higher mean values over population mean for pod length and number of pods per node.

Genotypes like EC 341995, NIC 11249, BDJ 42-174, DMR-11 and EC 381864 were observed to be high yielding and stable but their corresponding 'bi' values were significantly greater than unity. This shows that these genotypes would perform better in favourable conditions and hence could be recommended for cultivation in high fertility areas and for better management practices. However, genotype like DMR 1 had mean seed yield greater than the population mean and was stable ($S^2d_i = 0$) but the 'bi' value was found significantly lower than unity. It indicated that this genotype would perform better in poor environment conditions and hence this genotype can be used as a donor parent to breed a suitable line for poor environment.

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