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Stability analysis of vegetable cowpea yield and its components using Eberhart and Russel model

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Abstract

Study the extent of stability parameters in vegetable cowpea for twelve traits and 24 hybrids along with 11 parents were evaluated with three replications in randomized block design under four environments. Phenotypic stability by Eberhart and Russel model indicated highly significant genotype × environment for majority of traits, emphasizing the different reply of genotypes to varied environments. This information is crucial for breeders to select cultivars that exhibit stability across diverse environmental conditions. Linear and non-linear elements in gene × environment relation was highlighted through the analysis of variance of phenotypic stability. None of the parents or hybrids was found to be average stable for entire characters across environments. Among the identified stable hybrids for green pod yield per plant (g), GP 30 × Pusa falguni studied as the best-performing hybrid.

Keywords: Vegetable cowpea, hybrids, genotype × environment, Eberhart and Russel model

Introduction

Vegetable cowpea act an important function in human diet and nutrition also green tender pods form an excellent nutritious vegetable and have the potential. It is also known as 'vegetable meat'. Tender marketable pods contain approx 4.3 g protein, 2.0 g fiber, 8.0 g carbohydrates, 74.0 mg phosphorus, 2.5 mg iron, 0.9 mg mineral matter and 13.0 mg vitamin-C *per* 100 g of edible pods (Goud *et al.*, 2020) [10]. The genus *Vigna* encompasses about 160 species distributed mostly in Asia and Africa and the mechanisms of pod dehiscence and seed dormancy are lost after domestication There are often fewer branches, bigger leaves, thicker stems, fewer nodes, and shorter internode lengths. At the end of this procedure, self-supporting plants that are well suited to monocrop husbandry systems are evaluated (Smart, 1976) [20]. Vegetable cowpea used for reducing plasma cholesterol within the body. It is an excellent source of dietary Protien and fiber (Goud *et al.*, 2020) [10].

Cowpea used in the young leaves, green pods and as vegetables. Dry seeds are used in various food preparations and the haulms are fed to livestock as nutritious supplement. Grain cowpea is legume crop dry regions of the tropics and subtropics, which can be grown in relatively less sandy soils with a minimum annual rainfall of 200 mm. It is also a drought tolerant crop and ideally suited to harsh conditions where many crops are unable to flourish (Bisikwa *et al.*, 2014 and Ddmuliral *et al.*, 2015) [4, 7].

Though it is native of west Africa (Vavilov, 1951) [22] but (Steele, 1976) [21] Ethiopia suggest it as the primary and Africa as the secondary centre of diversity for cowpea and the cowpea introduced in India sub continent about 3500 years ago along with millets and sorghum. The major cowpea growing countries in the world are Nigeria, Burkina, India, Sri Lanka, Burma and Bangladesh. In India, it is mainly grown in Maharashtra, Rajasthan and Gujarat. It cultivated in arid, semi arid tropics and subtropics. Non-specific wild forms are found in Africa (Marechal *et al.*, 1978) [12].

The evolvement of genotype-environmental interactions gives an idea of the buffering capacity of the population under study. Stability analysis is done from the data of repeated experiments carried out in multiple locations or for several years on the same location or both. Selecting stable genotypes is acknowledged to include testing genotypes in various situations with unexpected variance. (Eberhart and Russel, 1966) [8]. In order to identify stable genotypes, the genotype by environment interactions must be divided into stability statistics.

Researchers have been able to discover genotypes that are broadly adaptable for usage in breeding programmes according to stability indices.

Materials and Methods

In Vegetable cowpea crossing conducted in *kharif* 2022 at Agronomy Instructional Farms, Sardarkrushinagar dantiwada agricultural university, S. K Nagar, employing eight lines and three testers. The summer 2023, evolution was carried out by using 11 parents, 24 crosses at two distinct locations (Sardarkrushinagar and Aseda) with two sowing dates (13th February and 28th February). Four environments created 13thFebruary at Sardarkrushinagar (E_1) and Aseda (E_2) and 28th February at Sardarkrushinagar (E_3) and Aseda (E_4) for stability study. The plot size consisted of single row of 6 meter length. The inter and intra row distance were 90 cm and 60 cm, respectively. Geographic and edaphic information of sardarkrushinagar and aseda in Table 1. The climate of this area is typical sub-tropical type characterized by semi-arid and arid condition. The weather condition during the experimental period was normal and favorable for crop growth. To evaluate the genotype stability and environmental variance stability parameters were used Eberhart and Russell (1966) [8].

Results and Discussion

Among plant breeders, producing genotypes with broad adaptability has always been the aim. Growing breeding lines throughout time and space has become a difficult component of every plant breeding effort in order to accomplish this aim. A significant G × E interaction also has the effect of reducing progress from selection (Comstock and Moll, 1963) [6]. Results on breeding techniques, selection programmes, and testing processes for agricultural plants requires an understanding Considering the kind and proportional importance of many components of the G × E interaction (Baker, 1969) [3].

An analysis of variance showed that for every feature under study, the mean squares owing to environments (E) and genotypes (G) were determined to be extremely significant Table 2. The findings showed that the genotypes and settings under study were diverse. When compared to pooled error, the G × E interaction was significant for every character (with the exception of days to pod girth). This finding suggested that these characteristics' genotypes interacted differentially with environmental variables [El. shaieny *et al.* (2015) [9], Sharma *et al.* (2022) [18] and Atakora *et al.* (2023]. However, G × E interaction was significant for days to flowering, days to first picking, number of primary branches per plant, plant height, pod length, number of pod per plant, pod weight, number of cluster per plant, number of pod per cluster, green pod yield per plant, crude protein content (Table 2).

Mean square due to E + (G × E) component was important for each and every characteristic. except pod girth and variations due to environment (linear) and a linear component of G × E were significant for every character with the exception of pod girth revealing the linear contribution of environmental effects and additive environment variance Patel and Jain (2012) [16], Chaudhari *et al.* (2013) [5] and Nassir *et al.* (2021) [14]. For most of the features under study, the majority of the overall variance could be explained by the environments' linear response, as seen by the larger magnitude of mean squares attributed to environments (linear) than genotypes × environments (linear).The non-linear components of G × E interaction (pooled deviation) were significant for days to flowering, green pod yield per plant and crude protein content (Table 2). This implied that the differential response of stability comprised both predictable and unexpected components. for this trait[Ddmuliral *et al.* (2015) [7], Aquino *et al.* (2016) [1] and Manivannan *et al.* (2019) [11].

The observation was made that E_4 was favourable for number of primary branches per plant, plant height, pod length, pod girth, number of pod per plant, number of cluster per plant, number of pod per cluster, green pod yield per plant, crude protein content. E_4 was the most favourable regarding yield and the characters that contribute to it, while E_1 was discovered to be the most unfavourable for green pod yield per plant and majority of related traits (Table 4).

The response of a genotype is measured by linear regression (bi), while stability is measured by deviation from regression (S^2di). Regression coefficient (bi) values are evaluated as unity in the current study if they are determined to be non-significant. If the S^2di values for the regression deviation are determined to be non-significant, they are regarded as being inside the "minimum deviation," or zero. As a result, genotypes with the aforementioned values are regarded as stable. Based on the genotype mean values and regression coefficient, the response or sensitivity to environmental changes is determined Singh and Singh (1980) [19] and Mehra and Ramanujam (1978) [13] used to evaluate the genotypes for stability.

The unit regression coefficient and non-significant value of departure from regression were shown for average stable parents and hybrids. Because of their lower mean (preferred) and non-significant value of regression deviation, unit regression coefficient (bi) values are thought to be generally stable and adaptable to a variety of events in days to flowering parents (GP 9, GP 52, GP 38 and Pusa falguni) and hybrids were GP 9 × GDVC 2, GP 9 × Pusa falguni, GP 38 × AVCP 1 and GP 52 × Pusa falguni. In days to first picking parents (GP 9, GP 52 GP 18 and GP 44) and hybrids GP 9 × Pusa falguni, GP 18 × Pusa falguni and GP 10 × Pusa falguni found average stable (Table 3).

Due to their almost unit regression coefficient (bi) values, larger mean (which is ideal), and non-significant regression deviation value, they are thought to be highly adaptable to a favorable conditions in number of primary branches per plant hybrids GP 52 × Pusa falguni and GP 30 × Pusa falguni, in plant height hybrid GP 30 × Pusa falguni, in pod length parent GP 38 and hybrids GP 38 × GDVC 2, GP 38 × Pusa falguni and GP 38 × AVCP 1, in number of pod per plant parents (GP 44 and GP 30) and GP 30 × Pusa falguni, GP 44 × GDVC 2 and GP 9 × GDVC 2, in pod weight parents (GP 10 and GP 38) and hybrids GP 52 × Pusa falguni and GP 9 × GDVC 2, in number of cluster per plant parents (GP 58 and GP 30) and hybrids GP 30 × Pusa falguni, GP 9 × Pusa falguni and GP 58 × GDVC 2, in number of pod per cluster line (GP 30) and hybrids GP 30 × Pusa falguni, GP 38 × GDVC 2 and GP 38 × Pusa falguni, in crude protein content line (GP 10) and hybrids GP 38 × Pusa falguni, GP 58 × AVCP 1 and GP 10 × Pusa falguni found average stability in different traits (Table 3).

In greed pod yield per plant hybrid GP 30 × Pusa falguni results (Table 5) average stable hybrid, GP 9 and Hybrids GP 18 × GDVC 2, GP 18 × AVCP 1 and GP 9 × GDVC 2 showed significant deviation from regression (S^2di) which showed unstable result. Line (GP 44 and GP 18) and Hybrids GP 44 × GDVC 2, GP 44 × Pusa falguni and GP 44 × AVCP 1 reflects less than average stability of genotypes which means they were sensitive to environmental changes but adaptable to favourable environments. Line GP 10 and hybrids GP 10 × GDVC 2, GP 10 × Pusa falguni and GP 10 × AVCP 1 reflects more than average stability of genotypes with adaptable nature to poor environments in green pod yield per plant (Table 3).

In the present investigation, Upon examining these factors for every genotype independently, it was found that none of the parents or hybrids demonstrated average stability across all features. Because the genotype for these traits may not display uniform responsiveness and stability patterns at the same time, it is impossible to generalise about the stability of the genotype for all of the characters. It is consequently advised that in order to develop stable hybrids, genuine hybrids would need to be tested in a variety of conditions, and the choice of parents should be made primarily on how well they combine. It has been found that the stability of its component features leads to the genotype stability for green pod yield per plant. Nunes *et al*. (2014) [15], Santos *et al*. (2015) [17], Manivannan *et al*. (2019) [11] and Sharma *et al*. (2022) [18] had proposed incorporating stability into breeding operations by using prospective and stable genotypes.

Table 1: Geographic and edaphic details of Sardarkrushinagar and Aseda

S. No.	Particulars	Sardarkrushinagar	Aseda
1.	Lattitude	24° 32' North	24° 17' North
2.	Longitude	72° 30' East	72° 18' East
3.	Altitude	154.5 m above mean sea level	134.1 m above mean sea level
4.	Soil type	Sandy loam with pH 7.5	Sandy loam with pH 7.5
5.	Agroclimatic zone	North Gujarat Agro-climatic Zone-IV of Gujarat State	North Gujarat Agro-climatic Zone-IV of Gujarat State

Table 2: Analysis of variance over environments for stability for different characters in vegetable cowpea

Source of variation	df	Days to flowering	Days to first picking	Number of primary branches per plant	Plant height	Pod length	Pod girth	Number of pod per plant
Genotypes (G)	34	74.06**	86.78**	5.96**	3728.74**	38.13**	0.007**	1311.07**
E + (G × E)	105	2.87**	3.09*	0.14**	19.12**	1.38**	0.000	29.17**
Environments (E)	3	18.24**	11.94**	2.10**	334.99**	24.12**	0.001**	527.55**
Genotypes × Environments (G × E)	102	2.42**	2.82*	0.09**	9.83*	0.71**	0.000	14.52**
Environments (linear)	1	54.71**	35.82**	6.29**	1004.96**	72.36**	0.002**	1582.66**
G × E (linear)	34	3.48**	4.55**	0.12**	11.20*	0.95**	0.000	15.99*
Pooled deviation	70	1.83	1.91**	0.07	8.88	0.58	0.000	13.38
Pooled error	272	1.63	1.13	0.05	7.38	0.45	0.000	10.00

Source of variation	df	Pod weight	Number of cluster per plant	Number of pod per cluster	Green pod yield per plant	Crude protein content
Genotypes (G)	34	905.92**	2.11**	4.93**	13257.65**	11.03**
E + (G × E)	105	9.82**	0.12**	0.10**	643.55**	0.82**
Environments (E)	3	122.12**	1.13**	1.10**	8797.73**	3.91**
Genotypes × Environments (G × E)	102	6.52**	0.09**	0.07**	403.72**	0.73*
Environments (linear)	1	366.35**	3.40**	3.31**	26393.19**	11.72**
G × E (linear)	34	8.85**	0.15**	0.14**	647.90**	1.19**
Pooled deviation	70	5.20	0.06	0.03	273.58**	0.48*
Pooled error	272	4.42	0.05	0.04	139.81	0.34

*,** Significant at 5 and 1 percent level, respectively

Table 3: Stability parameters for yield and yield related traits in vegetable cowpea

Genotypes	DF			FP			NOB			PH			PL			NOP		
	Mean	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**
GP 52 × GDVC 2	48.50	-0.23	-0.72	57.58	-1.20	2.29*	6.18	1.06	0.02	40.86	1.44**	-1.24	22.30	1.27**	-0.16	54.87	1.92**	6.53
GP 52 × AVCP 1	49.42	-0.20	-0.28	58.33	-1.29+	-0.09	6.13	1.00	0.02	39.34	1.44**	-1.24	22.19	1.27**	-0.17	53.44	1.76**	5.75
GP 52 × Pusa falguni	47.83	-0.28	-0.52	57.17	-1.01+	-0.14	7.05	1.06	0.02	44.46	1.40**	-0.41	25.08	1.29**	-0.16	66.47	2.07**	14.41
GP 18 × GDVC 2	50.42	0.63	6.11**	59.83	0.92	0.73	7.15	1.72**+	-0.03	74.68	1.31*	2.66	20.90	2.42**++	-0.21	115.95	1.94**	14.64
GP 18 × AVCP 1	51.33	0.73	4.07*	60.67	0.23	1.63	5.90	1.39**	-0.01	59.27	1.58**	-0.12	16.07	1.83**	0.20	99.61	1.91**	9.18
GP 18 × Pusa falguni	49.50	0.48	5.36*	59.42	0.07	1.14	5.95	1.45**	-0.02	58.95	1.58**	-0.12	16.28	1.81**	0.19	102.27	1.88**	7.84
GP 58 × GDVC 2	59.33	2.27*	-0.31	71.33	5.41**++	0.79	9.12	2.15*	0.14*	145.70	1.86**	1.70	17.48	1.69**+	-0.21	60.74	1.23*	7.90
GP 58 × AVCP 1	60.00	2.81*	0.63	71.83	4.50**++	-0.74	8.72	2.15*	0.14*	132.60	1.86**	1.70	17.12	1.33**	0.00	59.74	1.03	11.06
GP 58 × Pusa falguni	58.17	1.98*	-0.09	71.42	4.91**++	1.68	8.83	2.22*	0.15*	131.50	1.86**	1.70	16.95	1.51**	-0.11	59.06	0.94**	-7.50
GP 9 × GDVC 2	40.75	1.30	0.53	51.42	-1.34	0.44	9.00	1.52**	-0.02	74.38	0.18++	-4.75	18.39	1.41*	0.60	74.17	1.21	19.61
GP 9 × AVCP 1	47.83	1.71	0.59	58.75	-0.41	2.39*	7.55	1.72**+	-0.03	60.41	0.00++	-6.37	14.05	1.16**	-0.04	59.53	1.42*	13.12
GP 9 × Pusa falguni	45.67	1.48	-0.34	57.83	0.46	1.16	7.80	1.25*	0.00	57.58	0.00++	-6.37	14.30	1.16**	-0.04	60.30	1.42*	13.15
GP 38 × GDVC 2	50.83	0.39	2.09	60.00	3.27*	0.74	5.98	0.21	0.03	48.93	1.18	4.48	20.14	0.89	0.56	49.87	0.75	6.09
GP 38 × AVCP 1	47.58	0.71	0.69	57.75	2.35*	0.20	5.92	0.21	0.03	50.18	1.18	4.48	19.71	0.89	0.56	49.77	1.05	7.62
GP 38 × Pusa falguni	50.67	0.69	3.22	60.25	3.72*	1.61	6.02	0.08	0.01	48.51	1.18	4.48	19.81	0.89	0.56	49.59	0.68	5.17
GP 44 × GDVC 2	47.00	2.61**++	-1.30	56.92	1.11	3.07*	7.87	2.05**++	-0.05	56.43	0.84	-0.27	19.10	1.27**	-0.17	76.28	0.68	-4.04
GP 44 × AVCP 1	53.50	2.92**++	-1.55	63.25	0.86	1.65	6.57	1.92**++	-0.04	49.56	0.84	-0.27	14.54	1.27**	-0.17	61.79	0.76*	-3.40
GP 44 × Pusa falguni	52.75	2.53**++	-1.58	62.00	1.02	1.45	6.68	1.72**++	-0.03	48.36	0.84	-0.27	14.76	1.27**	-0.17	62.06	0.68	-4.04
GP 10 × GDVC 2	49.75	-1.68**++	-0.78	60.25	-2.74**++	-0.58	5.77	-0.29	0.07	39.91	-0.12	4.66	18.70	-0.38+	0.51	37.81	-0.06+	-1.27
GP 10 × AVCP 1	51.58	-1.59+	0.76	61.00	-2.39+	0.63	5.70	-0.28	0.12*	38.41	-0.12	4.66	18.53	-0.38+	0.51	37.37	-0.05+	-1.28
GP 10 × Pusa falguni	49.00	-1.79*++	-0.69	59.50	-1.30	0.40	5.87	-0.15	0.11	42.34	-0.12	4.66	18.59	-0.38+	0.51	37.71	-0.06+	-1.27
GP 30 × GDVC 2	51.67	3.18**++	-1.53	62.00	2.98*	0.34	5.90	0.33	-0.02	60.46	1.20	8.99	15.16	0.89	0.56	67.59	1.00	6.85
GP 30 × AVCP 1	52.33	3.18**++	-1.53	62.42	2.22	1.08	5.92	0.27	-0.02	61.61	1.20	8.99	14.94	0.89	0.56	66.04	0.93	7.92
GP 30 × Pusa falguni	46.42	2.22**++	-1.31	57.00	1.67*	-0.44	6.83	0.59	0.01	68.57	1.30	8.30	17.90	1.14	1.18*	79.37	1.15	7.62
GP 52	48.42	-0.20	-0.28	57.17	-0.47	0.60	6.48	0.93	0.03	38.53	1.47**	-1.28	22.83	1.26**	-0.16	52.86	1.76**	3.03
GP 18	50.33	0.00	3.37*	60.33	0.87	2.15	5.66	1.30*	-0.01	59.42	1.40**	-0.17	15.25	1.81**	0.19	97.55	1.38*	7.52
GP 58	63.42	2.38**	-0.68	73.83	3.92**++	-0.48	10.12	2.15*	0.14*	155.90	1.86**	1.70	17.51	1.23**	-0.03	57.73	0.77*	-4.03
GP 9	45.58	1.31	0.18	56.92	0.63	-0.28	7.92	1.32*	-0.01	69.34	1.31	19.04*	13.15	1.16**	-0.04	58.12	1.17*	5.74
GP 38	48.75	0.42	1.61	59.42	3.48*	1.84	5.82	0.40	-0.01	51.65	1.18	4.48	21.91	0.89	0.56	51.92	0.90	6.24
GP 44	50.08	2.78**++	-1.42	60.58	0.77	1.73	6.63	2.21**++	-0.02	52.93	0.84	-0.27	14.31	1.27**	-0.17	65.42	0.53	-3.18
GP 10	49.67	-2.10**++	-1.41	60.00	-2.22++	0.37	5.37	0.18++	-0.05	38.47	-0.12	4.66	19.63	-0.38+	0.51	38.40	0.17++	-7.69
GP 30	51.50	2.90**++	-1.35	62.17	1.64*	-0.45	5.83	0.33	-0.02	60.32	1.21	4.62	14.33	0.92	0.52	65.40	0.71	6.87
GDVC 2	50.83	0.59	-1.40	60.08	1.52**	-0.93	5.75	0.19++	-0.05	47.87	0.65*	-4.51	14.21	0.20**++	-0.42	70.41	0.45**++	-9.61
AVCP 1	51.33	0.57*	-1.54	61.42	-0.11	2.25	5.75	0.31**++	-0.05	43.84	0.65*	-4.51	13.97	0.06**++	-0.41	67.84	0.46**++	-9.59
Pusa falguni	49.17	0.28	-1.41	59.50	0.95	-0.53	5.88	0.31**++	-0.05	46.86	0.65*	-4.51	14.12	0.20**++	-0.42	69.33	0.45**++	-9.60
	50.60			60.84			6.73			62.80			17.55			63.90		

Genotypes	PW			CPP			PPC			GPY			CP		
	Mean	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**	**Mean**	**bi**	**S^2di**
GP 52 × GDVC 2	38.93	1.29	2.52	5.28	2.36**++	-0.04	4.90	2.06*	0.03	226.89	2.06**	112.14	21.82	3.05**+	-0.08
GP 52 × AVCP 1	37.72	1.29	2.52	5.18	2.42**++	-0.03	4.72	2.09**	0.01	190.63	2.06**	112.14	21.65	3.05**+	-0.08
GP 52 × Pusa falguni	48.08	0.75	-0.86	6.48	2.32**++	-0.03	5.48	2.15**+	-0.02	257.88	2.09**+	27.84	21.75	3.05**+	-0.08
GP 18 × GDVC 2	43.71	0.75	-0.86	6.50	2.09*	0.01	5.85	1.57*	0.00	377.61	1.99*	328.99*	28.26	3.03**+	0.02
GP 18 × AVCP 1	32.50	1.29	2.52	5.18	2.04*	0.03	4.50	2.18**++	-0.03	300.12	2.00**	298.09*	24.16	2.95**++	-0.31
GP 18 × Pusa falguni	32.86	1.29	2.52	5.30	2.09*	0.01	4.67	2.37**++	-0.03	305.97	2.02**	250.73	25.04	2.91**+	-0.10
GP 58 × GDVC 2	35.66	1.50*	1.02	6.18	-0.42	0.01	2.50	0.44	0.02	194.81	0.40	64.69	24.32	-0.26	0.87*
GP 58 × AVCP 1	34.67	1.50*	1.02	6.00	-0.47+	-0.01	2.13	0.25	0.01	188.77	0.40	64.69	25.67	-0.34	0.67
GP 58 × Pusa falguni	35.25	1.50*	1.02	6.18	-0.42	0.01	2.23	0.44	0.02	191.05	0.40	64.69	24.07	-0.26	0.87*
GP 9 × GDVC 2	46.03	0.22	7.55	8.05	2.32	0.17*	5.87	2.26**	0.02	275.43	2.47**	504.04**	28.41	3.03**+	0.02
GP 9 × AVCP 1	33.66	0.66	9.64*	6.72	2.32	0.17*	4.32	2.75**	0.05	198.53	2.47**	504.04**	25.10	2.91**+	-0.10
GP 9 × Pusa falguni	34.85	0.66	9.64*	6.88	2.42	0.11	4.45	2.75**	0.05	221.03	2.47**	504.04**	25.21	2.91**+	-0.10
GP 38 × GDVC 2	52.10	1.39*	0.70	5.72	0.18	0.00	5.35	0.12	0.01	239.17	0.25	118.37	23.96	-0.53	0.01
GP 38 × AVCP 1	50.12	1.39*	0.70	5.43	0.22	0.01	5.17	0.44	0.02	234.28	0.25	118.37	23.63	-0.53	0.01
GP 38 × Pusa falguni	52.05	1.39*	0.70	5.77	0.22	0.01	5.23	0.44	0.02	236.24	0.25	118.37	26.02	-0.62	0.11
GP 44 × GDVC 2	70.73	2.33**++	-4.18	6.48	2.51**+	-0.01	5.50	2.43**++	-0.04	397.00	1.04**	-22.33	25.53	-4.16**++	0.05
GP 44 × AVCP 1	59.25	2.76**++	-4.09	5.08	2.51**+	-0.01	3.95	2.92**++	-0.04	331.29	1.04**	-22.33	22.82	-0.53	0.01
GP 44 × Pusa falguni	59.70	2.76**++	-4.09	5.22	2.51**+	-0.01	4.02	2.92**++	-0.04	334.11	1.04**	-22.33	22.87	-0.53	0.01
GP 10 × GDVC 2	75.80	-0.78+	2.87	5.52	-0.46+	-0.02	3.02	-1.19*++	-0.02	270.41	-0.26+	87.96	25.14	3.25*	0.45
GP 10 × AVCP 1	75.40	-0.78+	2.87	5.45	-0.46+	-0.02	2.85	-0.86++	-0.02	265.72	-0.26+	87.96	24.29	-0.36	-0.08
GP 10 × Pusa falguni	75.51	-0.78+	2.87	5.58	-0.46+	-0.02	3.03	-0.37+	-0.01	268.64	-0.26+	87.96	24.47	-0.36	-0.08
GP 30 × GDVC 2	35.14	1.41*	-0.14	5.97	-0.17	-0.02	4.97	0.44	0.02	212.92	0.47	269.41	24.87	-0.26	0.87*
GP 30 × AVCP 1	33.76	1.41*	-0.14	5.88	-0.12	-0.01	4.63	0.44	0.02	205.23	0.47	269.41	24.74	-0.26	0.87*
GP 30 × Pusa falguni	44.15	0.87	4.66	7.22	-0.12	-0.01	5.63	0.44	0.02	250.89	0.47	269.41	26.94	-0.35	0.84*
GP 52	36.52	0.95**	-4.17	5.18	2.38**+	-0.02	4.60	2.26**	0.02	190.10	2.06**	112.14	20.82	3.07**++	-0.24

GP 18	30.34	0.95**	-4.17	4.72	2.07**	-0.01	4.27	2.12**	-0.01	300.97	1.93**	223.42	24.46	3.07**++	-0.24
GP 58	34.16	1.50*	1.02	6.02	0.24	-0.05	1.90	0.08++	-0.04	185.59	0.40	64.69	23.94	-0.26	0.87*
GP 9	33.48	0.66	9.64*	6.82	2.42++	0.11	3.98	0.11++	-0.04	199.05	2.52**+	285.73*	24.67	3.05**+	-0.08
GP 38	50.15	1.25	0.39	5.58	0.18	0.00	5.05	-0.14++	-0.03	241.24	0.25	118.37	23.64	-0.53	0.01
GP 44	58.52	2.59**++	-2.65	5.12	2.34**++	-0.05	3.72	0.36	-0.03	345.73	1.04**	-22.33	22.43	-0.53	0.01
GP 10	74.92	-0.78	2.87	5.47	-0.63++	-0.04	2.60	-0.66**++	-0.03	275.11	-0.13++	-20.35	24.48	-0.36	-0.08
GP 30	33.15	1.41*	-0.14	6.00	-0.07	0.00	4.67	0.50	0.06	205.41	0.34	227.49	24.70	-0.26	0.87*
GDVC 2	29.86	0.14++	-4.23	5.27	0.17+	-0.04	5.05	0.11++	-0.04	209.98	0.43**++	-128.00	25.72	2.47**+	-0.19
AVCP 1	28.25	0.14++	-4.23	4.87	0.21	-0.04	4.25	0.38++	-0.04	191.55	0.43**++	-128.00	24.78	2.47**+	-0.19
Pusa falguni	29.30	0.14++	-4.23	5.52	0.26	-0.04	4.75	0.44**++	-0.04	202.97	0.43**++	-128.00	25.78	2.00**	-0.18
	45.03			5.82			4.28			249.21			24.46		

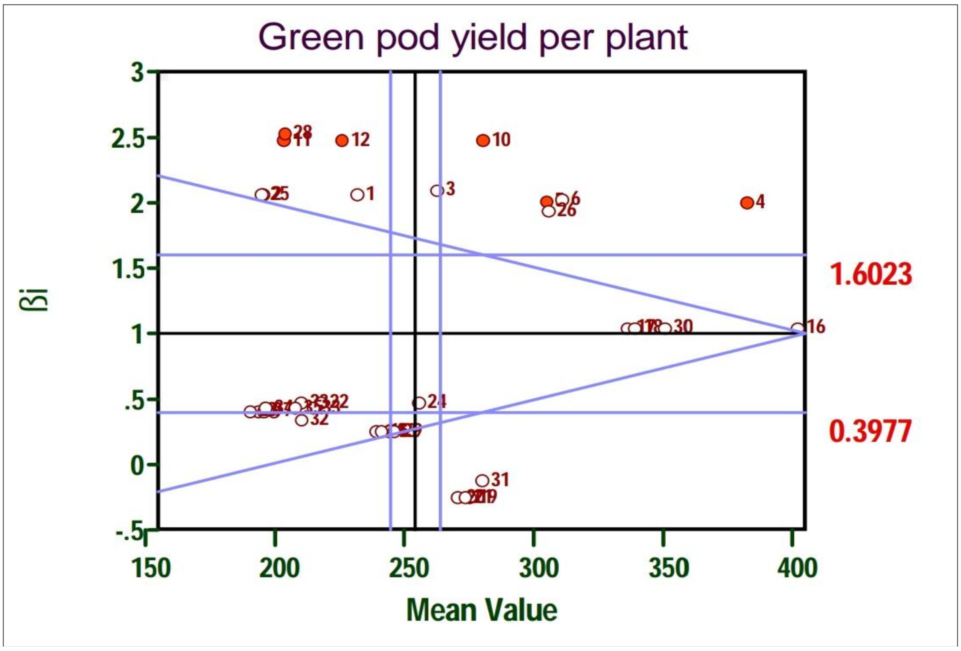
DF	:	Days to flowering	NOP	:	Number of pod per plant
FP	:	Days to first picking	PW	:	Pod weight
NOB	:	Number of primary branches per plant	CPP	:	Number of cluster per plant
PH	:	Plant height	PPC	:	Number of pod per cluster
PL	:	Pod length	CP	:	Crude protein content
PG	:	Pod girth	GPY	:	Green pod yield per plant

Table 4: Environmental index for various traits under various environments in vegetable cowpea

Sr. No.	Characters	Environmental index			
		E_1	E_2	E_3	E_4
1.	Days to flowering	0.71	-0.66	0.54	-0.58
2.	Days to first picking	0.78	-0.51	0.10	-0.37
3.	Number of primary branches per plant	-0.16	0.01	-0.19	0.34
4.	Plant height	-2.41	2.66	-2.94	2.68
5.	Pod length	-0.60	0.16	-0.67	1.11
6.	Pod girth	0.00	0.00	-0.01	0.01
7.	Number of pod per plant	-3.35	2.70	-3.31	3.96
8.	Pod weight	-1.42	2.20	-1.67	0.89
9.	Number of cluster per plant	-0.17	-0.02	-0.07	0.25
10.	Number of pod per cluster	-0.15	0.04	-0.12	0.23
11.	Green pod yield per plant	-12.17	4.85	-13.01	20.33
12.	Crude protein content	-0.21	-0.27	0.02	0.47

Table 5: Average stable hybrids identified on the basis of stability criteria green pod yield per plant (g) with their *per se* value and their performance in terms of other characters

Hybrids	Green pod yield per plant (g)	Average stable	Adaptable to favourable environments	Adaptable to unfavourable environments
GP 30 × Pusa falguni	250.89	NOB, PH, NOP, CPP, PPC, GPY	DF, FP	-



1 to 35 are the hybrids and parents according to serial number of Table 3

Fig 4: Graphical representation of the stability parameters for green pod yield per plant (g) in vegetable cowpea

Conclusion

For most variables, the analysis of variance of phenotypic stability revealed a very significant G × E interaction, suggesting that genotypes respond differently to diverse environments. The relevance of both linear and non-linear components in constructing the overall G × E interaction was shown by the significance of G × E (linear) and pooled deviation for green pod yield per plant and most of its associated features. For every character examined across all contexts, none of the parents or hybrids were found to have an average stability. For green pod yield per plant, GP 30 x Pusa falguni was found to be a stable hybrid over environments.

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