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Investigations on *Per se* Performance, Genetic Variability and Correlations in Vegetable Cowpea [*Vigna unguiculata* (L.) Walp.] Germplasm for Yield and Its Attributing Traits

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ABSTRACT

Background: Cowpea is a multiple-purpose, drought-tolerant, climate-smart and leguminous pulse crop. Recent studies established this crop as a potential vegetable crop with nitrogen fixation ability and round the year cultivation unlike French bean. In several crops, exotic collections imported into India have positive impact in release of new varieties. *Per se* performance evaluation is the best option for identification of high yielding varieties. Genetic parameters controlling the expression of yield and its components are essential in determining the effect of such genetic parameters and association among the characters enhancing the green pod yield of vegetable cowpea.

Methods: A set of eighty seven genotypes of vegetable cowpea including 59 exotic collections imported from International Institute of Tropical Agriculture (IITA), Nigeria; 24 indigenous germplasm collected from different parts of India and four released commercial varieties were evaluated in a randomized block design during *Kharif*, 2019. The analysis of variance by Panse and Sukhatme (1985), genetic parameters by Burton and De Vane (1953) and heritability in a broad sense and genetic advance by methods given by Allard (1960) and Johnson *et al.* (1955) were carried out to validate the results.

Result: The analysis of variance revealed that genotypes exhibited significant differences for all the characters. Based on *per se* performances, the exotic collections for flowering and maturity traits and check varieties followed by indigenous collections for yield and yield characters have exhibited superior performance. The highest range of variation was observed for green pod yield per plant. The highest variation was observed for pod yield per plant and number of pods per plant. The higher estimates of GCV and PCV (>20%) were registered by pod width, mature pod weight, number of pods per plant and pod yield per plant, which indicates partly the interaction of the genotypes with the environment influencing the expression of these characters. High heritability along with high genetic advance was observed for green pod yield per plant, pod length, pod width and number of pods per plant indicating that these traits were mainly governed by additive gene action and responsive for their further improvement. The maximum coefficient of variation was recorded for pod width followed by green pod yield per plant, pod weight and pod length. Green pod yield per plant has a positive and significant correlation with pod length, pod width, mature pod weight, number of pods per plant and number of seeds per pod. Hence, these characters should be considered, while selecting the genotypes for their further genetic improvement in vegetable cowpea.

Key words: Correlation, Genetic advance, Genetic variability, Heritability, *Per se* performance, Vegetable cowpea, Yield.

INTRODUCTION

Vigna unguiculata (L.) Walp., known as cowpea is a multiple-purpose, drought-tolerant leguminous pulse crop, grown in several dry tropical areas (Boukar *et al*., 2019). It has several features of a classical model plant for genomic studies, such as a relatively small diploid (2n=2x=22 chromosomes) genome of ~613 Mbp, a short annual life cycle and a highly selfing nature (Ehlers and Hall, 1997). It's rich in proteins (20-32%) and carbohydrates (50-60%). It's also regarded as a multi-use crop as a vegetable, for quality seed and fodder as well. Cowpea is referred to as the "poor man's meat" as its playing a crucial role in the human diet by virtue of its grains and leaves richer with lysine and tryptophan and vitamin C, iron and zinc (Goncalves *et al*., 2016; Jayathilake *et al*., 2018). It also enhances soil fertility due to its atmospheric nitrogen-fixing ability through rhizobium, hence a good legume crop to grow, whereas its tolerance to drought place this crop in a unique position in establishing in nutrition-sensitive food systems. In India, vegetable

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cowpea is a warm-season leguminous crops are grown especially for vegetable purposes. Cowpea in spite it's known to be a drought-tolerant one, compared with other crops, the erratic rainfall influences productivity of cowpea varieties (Boukar *et al*., 2019). Cowpea is one of the most drought and high-temperature tolerant legume crops producing high yields under terminal drought stress conditions and requiring less water than other cultivated legume species. All these characteristics emphasize cowpea as a good opportunity to increase the sustainability of agricultural systems and counteract climate changes (Ana *et al*., 2020).

Further, the general, yield of vegetable cowpea especially in marginal areas is still low and no single variety can be suitable for all growing conditions; whereby varietal requirements in terms of plant type, pod type, maturity and crop use pattern are highly diverse from region to region and these makes cowpea breeding programs more complex than any other crops. So, the choice of vegetable cowpea-specific genotypes adaptable to unfavourable environmental condition is determined by the careful breeding program (Singh *et al*., 2005). The objective of any breeding program is to develop desirable genotypes with high yield potential. Selection is an integral part of the breeding program by which genotypes with high productivity in a given environment are selected. So, selection for high yield is made difficult by the complex nature of this trait. The study of the genetic parameters controlling the expression of yield and its components are essential in determining the effect of such genetic parameters in enhancing the seed yield of cowpea (Khanpara *et al*., 2016; Nkoana *et al*., 2019; Pidigam *et al*., 2019; Saidaiah *et al.,* 2021). Therefore, the present investigation was attempted to investigate the *per se* performance, genetic variability and interrelation among the various yield and its attributing parameters of vegetable cowpea germplasm.

MATERIALS AND METHODS

The present investigation was taken up on 87 accessions of vegetable cowpea including 59 exotic germplasm collections imported from International Institute of Tropical Agriculture (IITA), Nigeria, 24 indigenous germplasm collected from different parts of India and four released commercial varieties *i.e.*, Kashi Kanchan, Kashi Unnati, Arka Samruddi and Arka Suman were evaluated in a randomized block design with two replications during *Kharif*, 2019 at Research farm, College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, Telangana, India situated at an altitude of 542.3 m above the mean sea level. Geographically, it lies at latitude of 17.19°N and longitude of 79.23°E. Recommended package of practices were followed to raise a good crop. Observations were recorded on flowering, maturity and yield contributing traits. The pod yield and its attributes were recorded on a plot basis. The analysis of variance was carried out as suggested by Panse and Sukhatme (1985). The genetic parameters *viz.*, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were estimated according to the methods suggested by Burton and De Vane (1953). The heritability in the broad sense and genetic advance were estimated employing the methods suggested by Allard (1960) and Johnson *et al*. (1955), respectively.

RESULTS AND DISCUSSION

The analysis of variance revealed that genotypes exhibited significant differences (Table 1) in respect of all the traits at 1% level of significance. While, pod width registered significant differences among the genotypes at 5% level of significance. Two characters' mature pod weight and pod length did not exhibit significant differences among genotypes. The highest variation was observed for pod yield per plant (45225.41**), number of pods per plant (1959.54**) (Table 1). Such a high variability for the above characters was also reported earlier by Narayanankutty *et al*., 2003; Thangam *et al*., 2020. Nkoana *et al*., 2019 reported highly significant differences among the accessions for all the traits in cowpea.

Assessment of *Per se* performance

Lack of information on germplasm characterization and evaluation restricts the effective use of germplasm (Kuldeep *et al*., 2019). Introduction and using them as parents in further improvement is one of the option, hence the exotic cultivars included in the study will be highly useful for vegetable cowpea improvement in India. In general, exotic collections followed by indigenous collections were superior (Table 2) for flowering and maturity traits based on per se performance, while, in respect of yield and its attributes, check varieties were superior followed by indigenous collections. In view of earliness reported in the present study, exotic collections can be further involved in suitable breeding programme with Indian varieties to incorporate earliness. When the seed colour (Fig 1) of all the studied genotypes was examined, greatest variation displayed by accessions that

Table 1: Analysis of variance of ten yield and its attributing characters of 87 germplasm of vegetable cowpea.

Character	Mean sum of squares		
	Replication (d.f.=1)	Genotypes (d.f.=86)	Error (d.f.=86)
Days to first flowering	1.3	141.21**	0.81
Days to 50% flowering	0.05	140.11**	0.44
Days to first fruit set	4.72	174.51**	0.35
Days to first harvest	7.8	170.34**	0.52
Pod length	6.13	10.00	0.29
Pod width	0.02	0.19*	0.002
Mature pod weight	0.238	6.74	0.03
Number of pods per plant	2.25	1959.54**	020
Number of seeds per pod	0.88	8.06**	0.15
Green pod yield per plant	289.82	45225.41**	48.88

*P = 0.05; **P = 0.01.

Fig 1: Continue...

Fig 1: Continue...

Fig 1: Vegetable cowpea seed colour variation.

inherits from generation to generation as seed colour is a qualitative trait. Hence, the present germplasm offers wider scope to serve the consumer preferences based on the seed colour.

Flowering characters

With respect to days to first flowering, EC-244018 (37 days) was earlier to flower (Table 3) followed by EC-390231, Kashi Unnati, IC-333106 and IC-91456, which were at par, while four genotypes *viz.*, EC-390266, EC-724452, EC-724775 and IC-206240 were late to flower, which took 65.50 days among all the genotypes. In regard to days to 50 per cent flowering, EC-244018 (41 days) followed by EC-390231, IC-333106, IC-91458 (41.50 days) and IC-20645 (42 days), Kashi Unnati, IC-249141, IC-257427, IC-219481 (43 days) and EC-390225 (43.50) were at par. While, IC-206240 and EC-724775 (71days) followed by EC-715197 (69.50 days) were very late to come to 50 per cent flowering among the genotypes studied. Sizeable amount of divergence among the cowpea germplasm was reported earlier by Hira Lal *et al.*, 2018, which is in line with the present investigation results.

Maturity characters

For days to first maturity, among the all the 87 genotypes, two genotypes, EC-290231 and IC-91458 (44.50 days) followed by EC-24018 and IC-333106 (46 days) were earlier to first maturity compared to rest of the genotypes. Around 19 genotypes had produced beans with early maturity than early maturing check variety Kashi Unnati (48 days). Whereas, two genotypes *i.e.*, IC-206240 and EC-724712 (75.50 days) followed by another 4 genotypes, took longer days to first maturity. For days to first harvest, EC-390231 and IC-91458 (50.50) followed by IC-333106 (51 days), EC-724374 and EC-724364 (51.50) and EC-724484 (52 days) were earlier among the genotypes. As many as 16 genotypes were earlier to harvest to early duration check, Kashi Unnati (53 days). Two genotypes, EC-715197 (80.50 days) and EC-724712 (81 days) had taken more days for first harvesting of matured beans. The present results are in tune with the reports of Valarmathi and Surendran, 2007.

Pod attributing traits

Length wise, longest pods were produced by Kashi Unnati (41 cm), while shorter pods were exhibited by three genotypes *viz.*, EC-725159 (9.35 cm) followed by EC-738091 (9.90 cm) and EC-724873 (10.70 cm). Wider pods were produced by EC-390231, EC-390204 (1.1 cm) followed by EC-72398, EC-244018, EC-390223 and IC-257427 (1.05 cm) and another 2 genotypes with more than 1cm pod diameter. Lowest pod diameter of 0.79 cm was registered by Kashi Unnati and more than 20 genotypes produced at par breadth measuring pods, which were at par. Similar reports are presented by Buleti *et al.*, 2020.

Kashi Unnati produced on an average of 19.50 gram weight green pods, which was highest among all the genotypes included in the study. As many as eight genotypes produced green pods with their pod weight ranging from

Table 2: Average performance of exotic (59) and indigenous (24) collections and check (4) varieties of vegetable cowpea.

Germplasm type	Days to first flowering	Days to 50% flowering	Days to first fruit set	Days to first harvest	Pod length	Pod width	Mature pod weight	Number of pods per plant	Number of seeds per pod	Green pod yield per plant
Exotic collections	50.31	54.73	60.34	66.05	15.14	0.52	4.71	29.63	14.25	148.46
Indigenous collections	48.54	51.90	57.00	62.38	14.23	0.55	3.70	50.59	15.13	178.06
Check varieties	44.25	47.88	53.50	57.63	30.69	0.70	13.91	58.50	31.50	292.75

Table 3: *Per se* performance of exotic (59) and indigenous (24) collections and check (4) varieties of vegetable cowpea for yield and its attributing traits.

Genotype	Days to first flowering	Days to 50% flowering	Days to first fruit set	Days to first harvest	Pod length	Pod width	Mature pod weight	Number of pods per plant	Number of seeds per pod	Green pod yield per plant
EC-101994	53.00	57.00	62.50	68.50	13.25	0.50	3.45	11.35	12.00	37.69
EC-244018	37.00	41.00	46.00	52.50	17.00	1.05	4.57	38.42	16.00	187.40
EC-343457	44.50	49.00	52.50	58.50	15.50	1.00	6.04	12.50	14.00	73.20
EC-367692	42.00	48.00	52.50	59.50	17.25	1.00	6.70	26.63	16.00	172.43
EC-367694	52.50	58.50	66.00	71.50	12.50	0.50	2.48	53.75	16.50	139.12
EC-390204	43.00	48.50	53.50	60.00	15.25	1.10	6.48	49.43	15.50	318.28
EC-390207	45.00	49.50	53.00	59.50	15.75	1.00	6.11	52.78	15.00	315.32
EC-390210	54.50	58.00	67.00	71.50	14.25	1.00	5.52	128.75	14.00	736.00
EC-390219	46.50	50.50	56.00	61.50	18.25	1.00	5.65	22.45	13.00	129.90
EC-390223	42.50	48.50	53.50	60.00	16.75	1.05	4.60	6.15	11.00	25.49
EC-390225	40.00	43.50	47.00	54.50	17.60	1.00	7.76	29.85	17.00	249.68
EC-390230	43.00	49.00	53.50	59.00	12.75	1.00	3.68	71.13	15.50	262.56
EC-390231	37.00	41.50	44.50	50.50	19.60	1.10	9.18	12.63	13.50	118.13
EC-390233	44.50	48.00	53.50	59.50	14.75	0.50	3.27	9.25	14.00	29.19
EC-390239	53.50	57.50	65.50	70.50	17.00	0.50	4.57	27.25	15.00	122.03
EC-390264	49.00	54.00	61.50	67.00	19.50	0.15	8.26	52.25	14.00	428.75
EC-390266	65.50	69.00	72.50	79.00	16.50	0.30	7.29	22.42	15.00	156.74
EC-390269	64.00	68.50	72.50	78.50	14.25	0.25	5.89	15.38	12.00	101.00
EC-390278	52.50	58.00	66.00	71.50	16.25	0.15	5.81	20.75	16.00	121.99
EC-424872	39.50	44.00	47.50	53.00	15.50	0.50	2.94	47.35	17.00	147.13
EC-715197	61.00	69.50	74.50	81.00	15.25	0.50	2.66	32.13	15.50	85.10
EC-723784	54.50	58.50	64.50	71.50	13.85	0.55	2.62	52.35	16.00	151.86
EC-723840	52.50	59.00	65.50	72.50	14.80	0.30	3.55	1.13	10.50	4.05
EC-723987	40.00	44.50	47.50	52.50	18.85	1.05	9.05	54.38	16.50	497.45
EC-724296	55.00	57.50	64.50	70.50	18.50	0.15	6.54	38.83	14.50	244.73
EC-724319	48.50	51.50	56.50	62.50	13.75	1.00	5.67	35.68	11.00	211.25
EC-724328	63.00	68.00	74.50	76.00	15.40	0.20	6.13	18.13	14.00	103.77
EC-724364	39.50	44.50	47.50	51.50	16.50	0.50	5.40	140.50	15.50	751.30
EC-724374	39.00	44.00	47.00	51.50	17.75	0.50	5.36	90.25	16.50	490.00
EC-724380	57.00	59.50	63.50	71.00	16.25	0.15	8.28	26.77	17.00	218.68
EC-724390	47.50	52.50	55.50	62.50	13.10	0.55	3.64	24.90	16.00	89.27
EC-724391	56.50	56.50	64.50	70.50	16.25	0.10	6.30	38.63	13.00	236.68
EC-724416	48.00	52.50	62.50	69.50	17.50	0.10	8.11	7.13	12.00	57.39
EC-724418	47.00	52.50	55.50	61.50	17.20	0.50	4.95	22.38	16.00	110.00
EC-724452	65.50	68.50	72.00	77.50	18.00	0.30	6.45	8.42	13.00	52.00
EC-724471	52.50	56.50	64.50	70.50	16.35	0.30	2.94	15.42	12.00	45.47
EC-724484	39.50	44.50	47.50	52.00	15.25	0.50	3.31	1.42	10.00	4.25
EC-724547	39.50	44.00	47.00	52.50	12.00	0.50	2.73	58.13	15.00	138.69
EC-724552	54.00	58.50	66.00	71.50	17.50	0.50	4.90	4.13	10.00	23.67
EC-724591	63.00	68.50	74.00	76.50	14.50	0.15	6.16	6.35	12.00	38.10
EC-724678	50.00	52.00	68.50	72.50	12.90	0.20	1.86	1.70	10.00	2.87
EC-724712	64.50	68.50	75.50	80.50	13.50	0.10	2.65	1.25	12.00	2.70
EC-724740	64.50	69.00	73.50	79.50	14.40	0.45	3.53	0.50	17.00	2.26
EC-724742	45.50	49.50	53.50	59.50	18.75	0.15	2.62	26.60	12.00	70.41
EC-724775	65.50	71.00	74.50	79.50	16.65	0.10	3.37	18.88	12.00	66.30
EC-724791	45.00	50.50	53.50	60.00	12.75	0.50	2.72	38.55	14.00	108.72
EC-724805	49.50	52.50	55.50	61.00	13.30	1.00	6.41	22.33	15.00	137.01

Table 3: Continue...

Table 3: Continue...

EC-724873	47.00	52.50	68.50	73.50	10.70	0.25	2.40	9.38	13.00	23.97
EC-724897	44.50	50.50	53.50	59.50	15.50	0.50	4.33	48.10	15.00	202.02
EC-724907	56.50	60.00	67.50	73.50	11.40	0.20	1.14	9.78	13.00	11.19
EC-725119	54.00	57.00	63.50	69.50	11.75	0.50	2.75	18.58	14.00	57.07
EC-725153	50.50	56.00	62.50	68.50	14.50	0.50	4.19	25.13	17.00	108.14
EC-725159	56.00	58.50	66.00	72.50	9.35	0.55	1.72	25.88	18.00	44.19
EC-725167	54.50	57.00	64.50	69.50	12.75	0.50	2.43	14.33	17.00	35.63
EC-734326	53.50	57.50	65.50	71.50	15.55	0.10	4.84	16.13	12.00	78.81
EC-738089	54.00	58.00	65.50	70.50	10.85	0.45	1.72	1.00	12.00	1.90
EC-738091	63.00	68.00	73.00	79.50	9.90	0.35	2.67	12.90	16.00	32.90
EC-738119	39.00	44.50	47.50	52.50	16.25	1.00	7.32	19.50	17.00	141.00
EC-738122	39.50	44.00	47.00	53.00	14.50	0.50	4.11	50.38	17.00	206.20
Average	50.31	54.73	60.34	66.05	15.14	0.52	4.71	29.63	14.25	148.46
IC-202100	50.50	53.00	62.50	59.00	12.90	0.50	2.84	18.88	13.00	52.84
IC-202718	59.00	61.50	69.00	73.00	14.50	0.10	3.47	0.50	14.00	2.10
IC-202762	59.50	63.00	65.50	71.50	12.50	0.30	4.28	0.50	13.00	2.20
IC-202796	49.50	53.50	61.50	69.00	14.75	0.50	4.14	49.75	14.00	207.50
IC-202813	40.50	44.50	47.50	53.50	17.80	0.20	4.25	14.75	15.00	59.50
IC-202820	60.00	64.00	69.50	74.50	16.75	0.30	3.80	13.63	14.00	48.55
IC-202824	50.50	54.50	60.50	66.00	13.10	0.50	2.89	53.00	16.00	143.60
IC-202827	50.50	53.50	62.00	69.00	13.75	0.50	2.85	121.38	16.00	318.38
IC-202924	61.00	63.50	70.50	77.50	14.10	0.40	3.59	52.42	15.00	187.08
IC-202931	40.50	44.50	47.50	52.50	13.60	1.00	4.18	54.13	16.00	215.98
IC-206240	66.50	71.00	75.50	79.50	12.00	0.95	3.60	103.25	14.00	376.51
IC-20645	39.00	42.00	47.50	54.00	15.75	0.55	4.38	74.50	16.00	311.60
IC-20720	54.50	58.00	64.50	69.00	11.50	0.30	1.14	55.63	17.00	60.42
IC-214751	50.00	51.50	57.50	64.50	15.50	0.55	4.20	114.00	16.00	459.26
IC-219481	39.00	43.50	47.50	53.50	13.50	0.50	3.37	20.50	14.00	70.70
IC-249141	39.00	43.00	47.00	53.00	12.20	0.45	3.33	87.00	15.50	273.91
IC-257427	40.00	43.00	47.00	52.50	15.25	1.05	6.68	22.50	12.00	155.83
IC-257449	48.50	53.50	55.50	60.50	14.35	0.50	3.83	54.60	16.00	214.47
IC-2574563	46.50	49.50	53.50	62.50	16.00	0.50	4.15	55.63	16.00	228.92
IC-259063	49.50	52.50	56.50	61.00	16.25	0.50	3.95	51.08	16.50	199.40
IC-259069	53.50	55.50	61.50	67.50	15.50	0.55	3.13	93.75	17.00	314.44
IC-333106	38.50	41.50	46.00	51.00	12.50	0.50	3.10	16.30	13.50	50.71
IC-91458	38.50	41.50	44.50	50.50	14.20	0.95	4.38	21.25	16.50	90.60
IC-97806	40.50	44.00	48.00	52.50	13.25	1.00	3.40	65.20	17.00	228.91
Average	48.54	51.90	57.00	62.38	14.23	0.55	3.70	50.59	15.13	178.06
Kashi Kanchan	39.50	46.00	52.00	56.00	41.00	0.72	17.50	61.25	40.00	309.50
Kashi Unnati	37.00	43.00	48.00	53.00	40.50	0.79	19.50	49.25	41.50	288.50
Arka Samruddi	54.50	53.50	58.00	61.50	21.50	0.65	11.75	64.00	22.50	305.50
Arka Suman	46.00	49.00	56.00	60.00	19.75	0.63	6.90	59.50	22.00	267.50
Average	44.25	47.88	53.50	57.63	30.69	0.70	13.91	58.50	31.50	292.75

7.29 g to 9.18 g, which was more than the higher weight pod bearing check variety, Arka Suman (6.9 g). In respect of number of pods per plant, EC-724364 had produced highest number of 140.50 pods. Eleven genotypes produced more number of pods ranging from 65.20 (IC-97806) to 140.50 (EC-724364) pods compared with higher number pod producing check variety, Arka Suman (64 pods). Owade *et al*. (2020) indicated cowpea pods and leaves can be consumed as boiled, blanched, dried, or fermented vegetables, which is cheaper source of protein. Always varieties with numerous pods are always appreciated by the farmers. Highest numbers of 41.5 seeds per pod were produced by Kashi Unnati. No germplasm produced good number of seeds per plant compared to all the four higher yielding check varieties included in the study. As many as 31 genotypes produced more seeds ranging from 16 to 18 per pod. Buleti *et al*. 2020

2020 reported that days to maturity, pod size and pods per plant revealed significant differences among the cowpeas.

Green pod yield per plant

Among the genotypes, with respect to green pod yield per plant, EC-390210 produced maximum of 736 grams green pod yield per plant (Table 3). Another 10 genotypes produced per plant green pod yield, ranging from 311.60 grams to 497.45 grams compared to high yielding check variety, Kashi Kanchan (309.50 g). The yield of cowpea has generally remained below the potential of the crop as farmers grow cowpea on marginally fertile and infertile soils. So, evaluation of germplasm for high yield is a regular criterion to identify new varieties. In this direction, from the present investigation, the out yielding accessions like EC-390210 can be evaluated in multi-locational trials before they are released for commercial cultivation. Morris *et al*., 2020 reported that eight Indian cowpea accessions produced significantly high protein content averaging 24.423% and pod yield and protein content had positive correlation. Higher yield always fetches good protein to diet. As reported by Molosiwa and Makwala, 2020, introduced genotypes performed better for nine of the characters, revealing the advantage of introduced genotypes, when twenty four cowpea genotypes were evaluated in field conditions for three consecutive seasons. The present study confirmed the same. Accessions without yield performance compared with check varieties are reported in different crops (Saidaiah *et al*., 2021 in jack bean; Ravi *et al*., 2021 in cluster bean; Pidigam *et al.,* 2021).

Genetic variability studies

With respect to range, pod yield per plant (1.90-751.30) followed by the number of pods per plant (0.50-140.50). Khanpara *et al*., 2015 reported the highest range of variation for pod yield per plant in vegetable cowpea. In all the traits, all the characters exhibited narrow differences between the value of PCV and GCV (Table 4). This indicated a low impact of the environment on the expression of all the quantitative characters. The same was reported earlier by Narayanankutty *et al*. (2005) and Thangam *et al*., 2020. The higher estimates of GCV and PCV (>20%) were registered by pod width (57.68, 58.18), mature pod weight (41.48, 41.67), the number of pod per plant (87.70, 87.70) and pod yield per plant (95.72, 95.82), respectively. The higher estimate of PCV over the corresponding GCV values for the characters studied indicate the influence of environmental factors in the expression of the traits under various environmental conditions. The higher estimates of GCV and PCV (>20%) for pod width, mature pod weight, number of pod per plant and pod yield per plant, indicate the scope for selection of these traits for further improvement. Narayankutty *et al*. (2003) and Vavilapalli *et al*. (2013) have reported in tune with the present results for green pod yield and its components in vegetable cowpea. Thangam *et al*., 2020 and Narayanankutty *et al*. (2003) reported high GCV for yield per plant and pod weight in vegetable cowpea. Low GCV values for days to first flowering and number of seeds

Table 4: Genetic variability, heritability and genetic advance of ten yield and its attributes in 87 vegetable cowpea germplasm.

Genetic parameter	Days to first flowering	Days to 50% flowering	Days to first fruit set	Days to first harvest	Pod length	Pod width	Mature pod weight	Number of pods per plant	Number of seeds per pod	Green pod yield per plant
Mean	49.80	53.91	59.37	64.99	14.88	0.53	4.42	35.69	14.51	157.02
Range	37.00- 66.50	41.00-71.00	46.00-75.5	50.50-81.00	9.35-19.60	0.10-1.10	1.14-9.18	0.50-140.50	10.00-18.00	1.90-751.30
PV	71.01	70.28	87.43	85.43	5.15	0.10	3.39	979.87	4.10	22637.14
GV	70.20	69.83	87.08	84.91	4.86	0.09	3.36	979.67	3.95	22588.27
EV	0.81	0.44	0.34	0.51	0.29	0.00	0.03	0.20	0.15	48.88
PCV%	16.92	15.55	15.75	14.22	15.25	58.18	41.67	87.70	13.96	95.82
GCV%	16.82	15.50	15.72	14.18	14.81	57.68	41.48	87.70	13.71	95.72
Heritability (Broad sense) %	99	99	100	99	94	98	99	100	96	100
GA	17.19	17.09	19.24	18.84	4.40	0.65	3.75	64.48	3.99	309.95
CV	1.80	1.24	0.99	1.10	3.63	7.66	3.88	1.25	2.65	4.45

PV= Phenotypic variance, GV= Genotypic variance, EV= Environmental variance, PCV%= Phenotypic coefficient of variation, GCV%= Genotypic coefficient of variation, GA= Genetic advance, CV= Coefficient of variation.

per pod have been reported by Sreekumar *et al*. (1996). High to moderate GCV and PCV values were found for number of pods per plant, pod yield per plant, pod weight, number of seeds per pod and pod length (Arup *et al*., 2014; Morris *et al*., 2020).

The higher values of heritability in the broad sense (>60%) were registered with all the traits ranging from 94% for pod length to 100 percent in case of days to first fruit set, number of pods per plant and pod yield per plant. Wide variation was observed for all these characters in the present study. Similar findings have been reported by other workers (Narayanankutty *et al*., 2005; Thangam *et al*., 2020).

With the help of variability and subsequent GCV alone, it is not possible to determine the amount of genetic variation that is heritable to the further generations. Burton and De Vane (1953) suggested that GCV combined with estimates of heritability would give the best results of genetic advance to be expected from the selection. In the present study, heritability values were high (>90%) for all the characters studied. High values of heritability for quantitative characters have also been reported by Thangam *et al*., 2020 and Narayanankutty *et al*. (2003). The accurate value for heritable variation can be estimated when heritability is combined with genetic advance. In the present study, high heritability coupled with high genetic advance was observed for pod yield per plant (g) and number of pods per plant. This may be due to the preponderance of additive gene action for these characters thereby indicating the advantages of selection for their improvement. High heritability coupled with high genetic advance for the above characters in vegetable cowpea has been reported by Narayanankutty *et al*., 2003; Kamara *et al*., 2017; Morris *et al*., 2020; Thangam *et al*., 2020. The value of PCV and GCV more or less equal were observed in the remaining characters which indicated that these characters were less influenced by the environment. High heritability along with high genetic advance was observed for green pod yield per plant, pod length, pod width and number of pods per plant also reported earlier by Khanpara *et al*., 2015. Other characters *viz.*, days to first flowering, days to 50% flowering, days to first fruit set, pod length, pod width, mature pod weight and number of seeds per pod has recorded high heritability of more than 90 percent but their genetic advance is very low (<30%) indicating the non-additive gene action for these traits. This implies the improvement of the above traits by pyramiding desirable genes through suitable hybridization programs.

The perusal of data revealed that the maximum coefficient of variation was recorded for pod width (7.66) followed by green pod yield per plant (4.45), pod weight (3.88) and pod length (3.63). The rest of the CVs for the rest of the characters among the genotypes exhibited less. It indicates that the characters measured with low CV are least influenced by environmental changes. In field experiments, higher CV is generally recorded due to heterogeneous properties of the climate and soil as well. The present study results showed that the heterogeneous

Table 5: Genotypic correlation coefficients among the flowering, maturity, yield and yield attributes of 87 vegetable cowpea germplasm.

Character	Days to first flowering	Days to 50% flowering	Days to first fruit set	Days to first harvest	Pod length	Pod width	Mature pod weight	Number of pods per plant	Number of seeds per pod	Green pod yield per plant
Days to first flowering	1	0.987**	0.960**	0.952**	-0.198	0.530**	-0.158	-0.217*	-0.219*	-0.262*
Days to 50% flowering	0.987**	1	0.963**	0.957**	-0.177	-0.515**	-0.140	-0.237*	-0.222*	-0.272*
Days to first fruit set	0.960**	0.963**	1	0.986**	-0.227*	-0.563**	-0.204	-0.249*	-0.290**	-0.292**
Days to first harvest	0.952**	0.957**	.986**	1	-0.209	-0.552**	-0.188	-0.244*	-0.265*	-0.288**
Pod length	-0.1976	-0.177	-.227*	-0.208	1	0.050	0.691**	-0.001	-0.055	0.262*
Pod width	-0.530**	-0.515**	-.563**	-0.552**	0.050	1	0.271*	0.265*	0.255*	0.337**
Mature pod weight	-0.158	-0.14	-0.204	-0.188	0.691**	0.271*	1	-0.005	0.022	0.364**
Number of pods per plant	-0.217*	-0.237*	-.249*	-0.244*	-0.001	0.265*	-0.005	1	0.468**	0.880**
Number of seeds per pod	-0.219*	-0.222*	-.290**	-0.265*	-0.056	0.255*	0.022	0.468**	1	0.384**
Green pod yield per plant	-0.262*	-0.272*	-.292**	-0.288**	0.262*	0.337**	0.364**	0.880**	0.384**	1

**Correlation is significant at the 0.01 level of significance.

*Correlation is significant at the 0.05 level of significance.

conditions are eliminated to the extent possible; hence, true genotypic effects are reflected in the CV. The cowpea is predominantly self-pollinated and hence, the CV reported is supported with earlier findings of Thangam *et al*., 2020 in cowpea. Hence, selection of parents differing in traits such as pod width, follow, green pod yield per plant, pod weight and pod length will be more useful in future breeding programs.

Genotypic correlation studies

The genotypic correlation studies provide reliable information on the nature and extent of relationship for bringing about improvement in yield and other traits. Days to first flowering were positive and significantly correlated (Table 5) with days to 50% flowering, days to first fruit set and days to first harvest, pod width, while negative and significantly correlated with no. of pods, no. of seeds per pods and pod yield per plant. Days to 50% flowering was positive and significant in correlation with days to first flowering, days to first fruit set and days to first harvest, at the same time significant and negatively correlated with no of pods, number of seeds per pods and pod yield per plant. Important maturity parameters days to first fruit set and days to first harvest were positively and significant among them and the other three maturity parameters. These two characters were significant and negative in correlation with yield and yield parameter *i.e.,* pod width, pod weight, number of pods, number of seeds per pods and pod green yield per plant.

Pod length was negative and significant with days to first fruit set and positive significant with mature pod weight and pod yield per plant, whereas, pod width was correlated as significant and negative with flowering parameters (days to first flowering and days to 50% flowering), maturity parameters (days to first fruit set and days to first harvest) and significant and negative with yield and yield attributes (mature pod weight, number of pods, number of seeds per pods and pod yield per plant). The mature pod weight was positive and significant in correlation with pod length and pod yield per plant. The number of pods, number of seeds per pods and pod yield per plant was negatively correlated with flowering parameters (days to first flowering and days to 50% flowering) and maturity parameters (days to first fruit set and days to first harvest), while, the correlation of number of pods per plant were positive and significant with pod width, number of seeds per pods and pod yield per plant. The numbers of seeds per pod were significant and positive with pod width, number of pods and pod yield per plant. Green pod yield per plant has a positive and significant correlation with pod length, pod width, mature pod weight, number of pods and number of seeds per pods. This is in accordance with the results of Narayanankutty *et al.* (2005); Pidigam *et al*., 2019; Morris *et al*., 2020; Thangam *et al*., 2020. Nkoana *et al*., 2019 reported positive and significant correlations of grain yield per hectare with the number of pods per plant and grain yield per plant in vegetable cowpea.

CONCLUSION

Our present investigation revealed that genotypes exhibited significant differences for all the characters among the genotypes as evidenced by the analysis of variance and higher ranges of variations. Based on *per se* performances, the exotic collections for flowering and maturity traits and check varieties followed by indigenous collections for yield and yield characters have exhibited superior performance. The highest variation was observed for pod yield per plant and number of pods per plant. EC-390210 produced maximum of 736 grams green pod yield per plant. The higher estimates of GCV and PCV (>20%), high heritability along with high genetic advance were observed for green pod yield per plant, pod width and number of pods per plant indicating that these traits were mainly governed by additive gene action and can be exploited for their further genetic improvement. The higher, positive and significant correlation of pod length, pod width, mature pod weight, number of pods per plant and number of seeds per pod with green pod yield per plant, demonstrated that these are the key characters for further improvement of yield in vegetable cowpea.

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