

Doi: [HTTPS://DOI.ORG/10.23910/2/2020.0377](https://doi.org/10.23910/2/2020.0377)

Genetic Variability, Correlation and Path Analysis Studies in Cowpea [*Vigna unguiculata* (L.) Walp.]

Santonu Das, C. Karak* and S. Roy

Dept. of Vegetable Science, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya,
Mohampur, Nadia, West Bengal (741 252), India

Corresponding Author

C. Karak
e-mail: todrck@gmail.com

Article History

Article ID: IJEP00377
Received in 04th July, 2020
Received in revised form 19th July, 2020
Accepted in final form 28th July, 2020

Abstract

The present investigation was carried out at Kalyani Simanta District Seed Farm, Kalyani, Nadia under BCKV during Pre-kharif season of 2018-19. Ten genotypes of cowpea were grown in randomized block design with three replications. The genotypes were studied for twelve characters viz, plant height at maturity, number of flower inflorescence⁻¹, number of primary branches plant⁻¹, leaf area, number of pods plant⁻¹, pod weight, number of grains pod⁻¹, pod length, biological yield plant⁻¹, area of primary leaf, hundred grain weight and grain yield plant⁻¹. The experimental studies revealed substantial amount of genetic variability among the genotypes under study. In general, phenotypic coefficients of variation were higher in magnitude than genotypic coefficient of variation. The characters pod yield plant⁻¹ and plant height at maturity showed comparatively higher estimates of genotypic and phenotypic coefficients of variation indicating high level of variability and ample scope for effective improvement. The higher estimates of heritability coupled with high genetic advance as percentage of mean indicated additive gene action for the above characters. Correlation studies revealed strong positive association of pod yield plant⁻¹, hundred grain weight with grain yield plant⁻¹. The path analysis studies indicated that the characters number of pods plant⁻¹ and days to first pod maturity bearing direct positive effect on grain yield, could be the selection criteria for genetic improvement of grain yield plant⁻¹ in cowpea population under study. Thus, the genotypes PL-3, PL-5, Mousumi Laffa are observed as desirable among the population for future use in breeding programme, as these genotypes had good performance for the important quantitative traits.

Keywords: Correlation, cowpea, genetic advance, variability, heritability, path analysis

1. Introduction

Cowpea [*Vigna unguiculata* (L.) Walp] is one of the most important, early, multiseason and multipurpose pulse crops grown extensively throughout the tropics and subtropics. It is a popular legume grown for tender green pod, fodder and dry grains. It is mostly cultivated as a mixed crop with a cereal or in association with a root or tuber crop in rice fallows. It fits well into different cropping systems, due to its relative drought tolerance. Cowpeas are efficient plant types requiring minimum natural resources but grains of high economic value. Cowpea belongs to the genus *Vigna* which comprises 169 species of which 120 are endemic to Africa, 28 to Asia, 14 to America and 7 to Australia. Being rich in protein and many other nutrients, cowpea is known as vegetable meat. On dry weight basis cowpea seeds contain 23.4% protein, 1.8 % fat and 3 % carbohydrates. Cowpea supplies 76 mg 100 g⁻¹ calcium, 5.7 mg 100 g⁻¹ iron, 430 mg 100 g⁻¹ phosphorous, 0.92 mg riboflavin, 0.18 mg thiamine and calorific value 342 calories 100 g⁻¹. Cowpea fixes atmospheric nitrogen through symbiosis with nodule bacteria (*Bradyrhizobium* sp.) to the tune of

40-50 kg nitrogen ha⁻¹ which maintains and restores soil fertility. Many of pulse crops can give reasonable yields even in exhausted soils and can survive the drought conditions.

Genetic variability is a key factor, which determines the amount of progress expected from selection. It is not only true for making selections but it also helps in selecting desirable parents in breeding programmes. Since many characters of economic importance are highly influenced by environmental conditions, study of genetic variability present in the base population is essential.

The selection of plants with desirable phenotypes from genetically variable population is the essential feature of all plant breeding programmes. The success of a breeder in changing the characteristics of a population depends upon the degree of correspondence between the phenotypic values and genotypic values. This is obtained from the estimates of heritability, which is a quantitative measure, which provides information about the correspondence between genotypic variance and phenotypic variance.

Yield is a complex character which is influenced by many



contributing traits both in positive and negative directions and is also largely subjected to the environmental fluctuations. So selection based on yield components is likely to be more effective. Correlation provides information about the relative contribution of various component traits towards yield. It measures the mutual relationship among various plant characters and helps in determining the yield components. This gives a reasonable indication for the breeder to base his selection on traits to improve economic yield and also plan a more efficient breeding programme.

The technique of path-efficient analysis, developed by Wright (1921), provides an effective means of partitioning the correlation coefficient to direct and indirect effects of the component characters towards yield. Based on the direct effect showed by a character on yield, breeder can consider that particular character for improvement.

2. Materials and Methods

Ten genotypes of cowpea from various locations were collected and grown at Kalyani Simanta District Seed Farm, Kalyani, Nadia under BCKV during Pre-kharif season of 2018-19 following Randomized Block Design with three replications with a Plot size of 4×0.25 m². The seeds were sown at a spacing of 30×10 cm² and 2 seeds were given per slot for uniform germination. After emergence plants were thinned as required. Five plants were selected randomly from each genotype in each replication and observations were recorded from each selected plants. Phenotypic and Genotypic coefficient of variation (PCV and GCV) was estimated as suggested by Burton and DeVane (1953). Heritability in broad sense (h^2) was calculated using the formula as suggested by Burton and DeVane (1953). Genetic advance (GA) was estimated as per Johnson et al (1955). The simple correlations between different characters at genotypic (g) and phenotypic (p) levels were estimated according to Searle (1965). Path co-efficient analysis was suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

3. Results and Discussion

The assessment of the extent of genetic variability, correlation and path analysis in cowpea for twelve quantitative characters in ten genotypes are presented hereunder :

3.1. Coefficient of variation

The estimates of phenotypic and genotypic coefficient of variation are presented in Table 1. In general phenotypic coefficient of variation (PCV) was greater in magnitude over the respective genotypic coefficient of variation. Least magnitude of phenotypic coefficient of variation was recorded for Number of flowers inflorescence⁻¹ (10.87), 100 seed weight (13.46) seed pod⁻¹ (17.7). Area of primary leaf (19.60), Plant height (19.90), Leaf area (20.52). Pods plant⁻¹ (21.71) indicated comparatively moderate estimates of phenotypic coefficient of variation. Maximum magnitude of phenotypic coefficient

of variation was observed for Pod weight at maturity (35.08) followed by Pod length (29.69) and Seed yield plant⁻¹ (23.67).

The amount of genetic variation present in the population was worked out in terms of genotypic coefficient of variation (GCV). The minimum genotypic coefficient of variation was exhibited by characters flower inflorescence⁻¹ (5.92), Number of primary branches (9.30), 100 seed weight (12.80) and Leaf area (19.48) recorded comparatively moderate values of genotypic coefficient of variation. Highest value of genotypic coefficient of variation was registered for pod weight (34.74) followed by pod length (28.85) and Seed yield plant⁻¹ (23.24). Leaf area (19.48) Pods plant⁻¹ (19.35) also showed moderate values of genotypic coefficient.

In the present study, there was considerable difference between GCV and PCV estimates for primary branches, flower inflorescence⁻¹, seeds pod⁻¹, This clearly indicates that these traits were largely controlled by environmental factors. Relative magnitude of difference between GCV and PCV was observed for pod length and number of seeds pod⁻¹ by Sreekumar et al. (1996).

The difference between GCV and PCV was low for pod weight, green pod yield plant⁻¹, pods plant⁻¹, plant height and 100-seed weight suggesting that the improvement could be made by phenotypic selection. The results obtained by Sreekumar et al. (1996) were contradictory to present study. This might be due to different genotypes and plant population used for the study.

The high GCV was observed for pod weight, green pod yield plant⁻¹, pods plant⁻¹, plant height. Similar results were observed for green pod yield and pod length by Sreekumar et al. (1996); for pods plant⁻¹, green pod yield, pod length and plant height by Chattopadhyay et al. (1996); for green pod yield by Rajaravindran and Das (1997); for plant height, seed yield and green pod yield by Vardhan and Savithramma (1998); for green pod yield, pods plant⁻¹, plant height and by Vardhan and Savithramma (1998); and for pods plant⁻¹ by Sawarkar et al. (1999) and Narayanakutty et al. (2003a). Thus, from the present finding it is evident that the yield component possessed considerable amount of genetic diversity.

3.2. Heritability and genetic advance

The GCV helps to measure the amount of genetic variability in a metric trait. However, it is not possible to measure heritable variation with the GCV alone. Burton (1952) advocated that a GCV together with the heritability would give the better picture of the amount of advance to be expected from selection. The heritable portion of the variation could be separated with the help of heritability estimates. The estimates of heritability and genetic advance are presented in Table 1.

High estimates of heritability in broad sense were exhibited by all the characters studied. Heritability ranged from 26.12% of primary branches to 98.07 % of pod weight. Very high estimates of heritability was exhibited by characters pod



Table 1: Genetic variability, heritability (H) and genetic advance (GA) as % of mean for various characters in ten genotypes of cowpea

Characters	Grand Mean	Range	GCV	PCV	H (%)	GA %	GA as % of Mean
Plant Height (cm)	39.16	27.36-57.89	18.74	19.90	88.72	14.24	36.35
Primary Branches	3.30	2.80-4.07	9.30	18.20	26.12	0.32	9.67
Flower Inflorescence ⁻¹	2.92	2.87-3.67	5.92	10.87	29.72	0.22	6.77
Area of primary leaf (cm ²)	11.59	8.79-16.75	17.54	19.60	80.07	3.85	33.19
Leaf area (cm ²)	34.06	27.02-47.39	19.48	20.52	90.12	12.91	38.09
Pod Length (cm)	21.73	12.78-31.87	28.85	29.69	94.00	12.50	57.50
Pod weight (g)	7.19	3.17-11.61	34.74	35.08	98.07	5.12	71.13
Pods plant ⁻¹	18.92	13.60-28.74	19.35	21.71	79.48	7.23	35.54
Seed pod ⁻¹	10.55	8.70-14.47	16.01	17.70	81.83	3.28	29.78
100 Seed weight (g)	14.97	11.58-18.04	12.80	13.46	90.37	3.60	25.00
Pod yield plant ⁻¹ (g)	113.70	69.87-151.46	21.87	22.64	96.37	50.69	43.52
Seed yield plant ⁻¹ (g)	25.75	21.12-39.26	23.24	23.67	93.29	14.87	47.00

weight (98.07%), Pod yield plant⁻¹ (96.37%), pod length (94%).

The estimates of heritability for other characters were 93.29 % for seed yield plant⁻¹, 90.37% for 100 seed weight, 81.83% for seed pod⁻¹, 79.48% for pods plant⁻¹, 90.12% for leaf area, 88.72% for plant height, 80.07% for area of primary leaf, 29.72% for number of flower inflorescence⁻¹, 26.12% for number of primary branches.

In the present investigation high to low heritability estimates were recorded for the characters studied. The present study indicated that phenotypic selection could be effective for the characters such as pod weight, green pod yield plant⁻¹, pods plant⁻¹, plant height, and 100-seed weight which had comparatively high heritability estimates. Similar findings were observed by Sreekumar et al. (1996) for seeds pod⁻¹ and days to 50 % flowering; Chattopadhyay et al. (1996) for pods plant⁻¹, green pod yield, pod length and plant height; Ram and Singh (1997) for pod length and green pod yield; Vardhan and Savithamma (1998) for primary branches plant⁻¹, green pod yield, pods plant⁻¹, plant height; Sawarkar et al. (1999) for primary branches plant⁻¹; Narayanakutty et al. (2003 a) for fruit yield, pods plant⁻¹ and weight of pods; and Resmi et al. (2004) for yield plant⁻¹, pods plant⁻¹ and pod weight.

The high heritability estimates enable breeders to bare the selection programme on phenotypic performance. Johnson et al. (1955) pointed out that heritability estimates along with genetic gain is more useful than the heritability value alone, in predicting the resultant effect from selecting the best individuals in soybean.

Plant height at maturity and pod yield plant⁻¹ showed comparatively higher estimate of genetic advance, i.e. 14.24 and 50.69. Minimum magnitude of genetic advance was recorded for number of flower inflorescence⁻¹ (0.22) and number of primary branches plant⁻¹ (0.32). Genetic advance as percentage of mean ranged from 6.77% (number of flower

inflorescence⁻¹) to 71.13% (pod weight). Pod length (57.50) and pod yield plant⁻¹ (43.52) showed higher estimates of genetic advance as % of mean, while Number of flower inflorescence⁻¹ (6.77) and Number of primary branches (9.67) showed the lowest values as % of mean.

The characters viz., pod weight, green pod yield plant⁻¹, pods plant⁻¹, clusters plant⁻¹, plant height, primary branches plant⁻¹ and had high genetic advance expressed as a percentage of mean accompanied by high heritability, which indicates that high heritability is probably due to additive gene effects (Panse, 1957). Hence, phenotypic selection may be useful for improving these traits. Similar findings were observed for pod length and green pod yield by Ram and Singh (1997); for green pod yield and pods plant⁻¹ by Rajaravindran and Das (1997); for plant height, primary branches plant⁻¹, secondary branches plant⁻¹ and green pod yield by Vardhan and Savithamma (1998); for green pod yield, pods plant⁻¹, plant height and secondary branches plant⁻¹ by Vardhan and Savithamma (1998); for branches plant⁻¹, plant height, pods plant⁻¹ and green pod yield plant⁻¹ by Sawarkar et al. (1999); for pod yield, pods plant⁻¹ and weight of pods by Narayanakutty et al. (2003a); and for pod yield plant⁻¹ and pod weight by Resmi et al. (2004).

High heritability with moderate genetic advance was observed for Leaf area, pods plant⁻¹ and moderate heritability as well as moderate genetic advance for pods cluster⁻¹ which suggests both additive and non additive gene effects were responsible for the control of these traits, respectively. Low heritability with low genetic advance was observed for Number of flower inflorescence⁻¹. This indicates that these characters are very much influenced by nonhereditary factors. Hence, selection would not be effective for improvement of such characters.

In the present study the characters viz., ten pod weight, green pod yield plant⁻¹, plant height, seed yield plant⁻¹ showed



relatively high heritability as well as high genotypic coefficient of variation and genetic advance. This indicated that the genotypes under study were highly diverse and had great genetic potential. Therefore, further improvement could be achieved with regard to these agronomic characters by practicing selection.

3.3. Correlation

In order to get knowledge of inter relationship between quantitative characters and yield, correlation coefficients were worked out for all the possible combinations among the characters under study at phenotypic and genotypic level and presented in Table 2, respectively.

Table 2: Prominent Genotypic (G) and Phenotypic (N) correlation between characters

Pair of characters	Correlation coefficient	
Plant height and primary branches plant ⁻¹	G:0.971*	P: 0.456*
Plant height and pod weight	G:0.628*	P: 0.588*
Plant height and pod plant ⁻¹	G:0.687**	P: 0.643**
Plant height and leaf area	G:0.870**	P: 0.752**
Leaf area and pod yield plant ⁻¹	G:0.945*	P: 0.711*
Leaf area and pod weight	G:0.818*	P: 0.772*
Flower per inflorescence and pods plant ⁻¹	G:0.773*	P: 0.516*
Flower per inflorescence and seed yield plant ⁻¹	G:0.758*	P: 0.366*
Pod per plant and seed yield plant ⁻¹	G:0.790*	P: 0.622*
Pods per plant and pod yield plant ⁻¹	G:0.453*	P: 0.515*
Seed yield plant ⁻¹ and pod yield plant ⁻¹	G:0.755*	P: 0.403*

N.B. *: Significant at ($p=0.05$) level, **: Significant at ($p=0.01$) level

3.3.1. Genotypic correlation coefficient

Plant height had significant positive correlation with primary branches plant⁻¹ ($r=0.971$), pod weight ($r=0.628$), pod plant⁻¹ ($r=0.687$), leaf area ($r=0.870$). Leaf area had significant positive correlation with pod yield plant⁻¹ ($r=0.945$), pod weight ($r=0.818$). They increase significantly with their changes. Flower inflorescence⁻¹ had positive significant correlation with pods plant⁻¹ ($r=0.773$), Seed yield plant⁻¹ ($r=0.758$). Pod plant⁻¹ had positive significant correlation with seed yield plant⁻¹ ($r=0.790$) and pod yield plant⁻¹ ($r=0.453$). Seed yield plant⁻¹ had positive significant relationship with pod yield plant⁻¹ ($r=0.755$).

3.3.2. Phenotypic correlation coefficient

The phenotypic correlation coefficients were worked out for all the characters and presented in Table 2. In general

genotypic correlation coefficients were higher in magnitude over the respective phenotypic correlation coefficients except for the association in few pairs of characters.

Plant height had positive significant phenotypic correlation with primary branches plant⁻¹ ($r=0.456$), pod weight ($r=0.588$), pod plant⁻¹ ($r=0.643$), leaf area ($r=0.752$). Leaf area had significant positive correlation with pod yield plant⁻¹ ($r=0.711$), pod weight ($r=0.772$). Flower inflorescence⁻¹ had positive significant correlation with pods plant⁻¹ ($r=0.516$), Seed yield plant⁻¹ ($r=0.366$). Pod plant⁻¹ had positive significant correlation with seed yield plant⁻¹ ($r=0.622$) and pod yield plant⁻¹ ($r=0.515$). Seed yield plant⁻¹ had positive significant relationship with pod yield plant⁻¹ ($r=0.403$).

Genotypic correlation permits the prediction of correlated response. It also permits the evaluation of the relative influence of various characters on yield. Searle (1965) suggested that average merit of characters in a population can be changed by means of selection programme based on phenotype of main trait, i.e. yield. However, such an improvement would be more reliable if indirect selection based on the other correlated traits is made. Thus, for rational improvement of yield and its components the understanding of correlation has been very useful.

Prior to breeding crops for higher yield, it is imperative to obtain information regarding the inter relationship of different characters with yield, assessment of high yielding genotypes the real association could be known through genotypic and environmental influence. The result of present study which revealed comparatively higher degree of genotypic correlation coefficient than their phenotypic counterparts in most of the characters indicated that there was a high degree of association between two characters at genotypic level and their phenotypic association was lessened due to the less influence of environment. In few cases, however, the phenotypic correlations were slightly higher than their genotypic counterparts which implied that nongenetic causes inflated the value of genotypic correlation because of the influence of the environmental factors. Similar findings were reported by Tewari and Gautam (1989), Mishra et al. (1994), Kar et al. (1995), Sreekumar et al. (1996), Vardhan and Savithramma (1998) and Pal et al. (2004).

Seeds pod⁻¹ recorded positive and significant association with pod yield plant⁻¹, Dhanasekar et al. (2010).

Pods plant⁻¹ recorded positive significant association with pod yield plant⁻¹, for pods plant⁻¹, Lal et al. (2007), Belhekar et al. (2003) for pods plant⁻¹, Patel et al. (2016) for pods plant⁻¹.

The present study revealed highly significant positive correlation between biological yield plant⁻¹ and grain yield plant⁻¹ both at phenotypic and genotypic level. Strong positive correlation was observed between plant height at maturity and biological yield plant⁻¹ both at phenotypic and genotypic levels. However, harvest index was found to be negatively



correlated with plant height.

Green pod yield plant⁻¹ was found to be highly significant and positively correlated with pods plant⁻¹ and ten pod weight. Hence, these characters could be taken as selection indices for the improvement of green pod yield. Similar results were obtained by Kar et al. (1995), Sreekumar et al. (1996), Vardhan and Savithramma (1998) and Pal et al. (2004) for pods plant⁻¹. Pal et al. (2004) reported positive correlation between green pod yield and average pod weight.

In the present findings the other desirable positive significant associations at genotypic and phenotypic levels were observed between pod length and seeds pod⁻¹. Similar results were also observed by Narayanakutty et al. (2003 b) for pod length and seeds pod⁻¹. While, the correlation coefficient values were found significant in desirable direction for pod weight with pod length, seeds pod⁻¹ and 100 seed weight; for pod length with pod weight; for pods plant⁻¹ with primary branches plant⁻¹.

In vegetable cowpea such type of desirable association between various yield related traits were reported by Narayanakutty et al. (2003 b), Tewari and Gautam (1989) and Pal et al. (2004). The association between various component traits may also be useful to the plant breeder while making the simultaneous selection of various traits for sorting out desirable plant type.

3.4. Path coefficient analysis

It was essential to measure the contribution of the various variables to the observed association; the correlation coefficients were further partitioned to assess the direct and indirect effects of various characters on yield. Fruit yield plant⁻¹ was taken as the dependent variable, which was the output of direct and indirect effects of independent characters viz., plant height at maturity, number of primary branches plant⁻¹, number of flowers inflorescence⁻¹, area of primary leaf, number of pods plant⁻¹, pod length, pod weight, seed pod⁻¹ and harvest index.

Yield is a complex character and multiplicative end product of several component traits. Some of them may be grouped as main components which directly contribute towards yield. Whereas, other may not contribute directly to the yield but indirectly may influence the yield by changing the behaviour and growth of different components. Therefore, it would be better to know how the yield is directly and indirectly influenced by other characters.

The different characters showing direct and indirect effect on yield is presented in Table 3. Pod yield plant⁻¹ was taken as the dependent variable. Plant height (0.572) and pod yield plant⁻¹ (0.524) showed direct positive effects with grain yield plant⁻¹. This character also had positive effects from Primary branches (0.008), primary leaf (0.131), seed pod⁻¹ (0.230). Flower inflorescence⁻¹ (-0.328), pod weight (-0.371) showed non-significant negative direct effects on seed yield plant⁻¹.

The residual effect of path analysis at phenotypic level was

Table 3: Characters represented direct effect on fruit yield

Characters	Correlation coefficient
Plant Height(cm)	0.572
Primary Branches	0.008
Flower Inflorescence ⁻¹	-0.328
Area of primary leaf (cm ²)	0.131
Leaf area (cm ²)	-0.002
Pod Length (cm)	0.112
Pod weight (g)	-0.371
Pod plant ⁻¹	0.009
Seed pod ⁻¹	0.230
100 Seed weight (g)	0.222
Pod yield plant ⁻¹ (g)	0.524

Residual effect = 0.1365

found to be about 0.1365.

The character biological yield plant⁻¹ had maximum positive correlation with grain yield plant⁻¹ phenotypic level. But positive indirect effect hundred grain weight, pods plant⁻¹, number of primary branches plant⁻¹ and number of grains pod⁻¹ resulted in strong positive correlation of biological yield plant⁻¹ with grain yield plant⁻¹. These results are in confirmation with that of Patil et al. (2003) who recorded negative direct effect of biological yield plant⁻¹ on seed yield.

Hundred grain weight had low negative direct effect on grain yield plant⁻¹ at both the levels. However, it's positive indirect effect *via*. harvest index, days to complete maturity, days to first flowering and days to first pod maturity resulted in high positive correlation with grain yield plant⁻¹ at genotypic level. The result is in agreement with the findings of Reddy et al. (1994) in green gram. On the other hand, Apte et al. (1989) reported positive direct effect of hundred grain weight or seed yield.

The character number of pods plant⁻¹ exhibited positive direct effect on grain yield plant⁻¹ at phenotypic level. The positive indirect effects expressed by pod yield plant⁻¹ was diminished by the negative direct effect of pod length, pod weight. This resulted in weak positive correlation of number of pods plant⁻¹ with grain yield plant⁻¹. Pod length had negative direct effect on grain yield plant⁻¹ at both genotypic and phenotypic levels. It had high positive indirect effect through biological yield plant⁻¹ whereas it showed negative indirect effects through plant height at maturity and grains pod⁻¹. This resulted in weak positive correlation of pod length with grain yield plant⁻¹. Apte et al. (1989) recorded negative direct effect of pod length on seed yield.

4. Conclusion

The experimental studies revealed substantial amount of genetic variability among the genotypes under study. The



higher estimates of heritability coupled with high genetic advance as percentage of mean indicated additive gene action for pod length, pod weight, seed yield plant⁻¹, pod yield plant⁻¹ along with pod plant⁻¹. Correlation studies revealed strong positive association of biological yield plant⁻¹, hundred grain weight plant⁻¹, pods plant⁻¹ with grain yield plant⁻¹. Thus, the genotypes PL-3, PL-5, Mousumi Laffa are observed as desirable among the population for future use in breeding programme, as these genotypes had good performance for the important quantitative traits.

5. References

- Apte, U.B., Chavan S.A., Jadhav, B.B., 1989. Path analysis in cowpea. *Agricultural Science Digest* 9(3), 165–167.
- Belhekar, P.S., Bendale, V.W., Jamadagni, B.M., Birari, S.P., 2003. Correlation and path-coefficient analysis of cowpea and Asparagus bean crosses in F₂ generation. *Journal of Maharashtra Agricultural University* 28(2), 145–147.
- Burton, G.W., 1952. Quantitative inheritance in grasses. *Proceedings of International Grassland Congress* 1, 277–283.
- Burton, G.W., DeVane, E.N., 1953. Estimating heritability in tall fescue from replicated clonal material. *Agronomy Journal* 45, 478–481.
- Chattopadhyay, A., Dasgupta, T., Som, M.G., Hazara, P., 1996. Variability studies in cowpea. *The Horticultural Journal* 9(1), 71–75.
- Dewey, D.R., Lu, H.K., 1959. A correlation and path coefficient analysis of component of crested wheat grass production. *Agronomy Journal* 51, 515–518.
- Dhanasekar, P., Dhupal, K.N., Reddy, K.S., 2010. Identification of RAPD markers linked to plant type gene in pigeonpea. *Indian Journal Biotechnology* 9, 58–63.
- Johnson, H.W., Robinson, H.F., Comstock, R.E., 1955. Estimates of genetic and environmental variability in soybeans. *Agronomy Journal* 47, 314–318.
- Kar, N., Das, T.G., Hazra, P., Som, M.G., 1995. Association of pod yield and its components in vegetable cowpea. *Indian Agriculture* 39(4), 231–238.
- Lal, H., Reddy, B.R., Nath, V., 2007. Biometrical studies of yield and related traits in advance breeding lines of bush type vegetable cowpea [*Vigna unguiculata* (L.) Walp.]. *Legume Research*, 40(1), DOI: 10.18805/LR-3799.
- Mishra, H.P., Ram G., Jha P.B., 1994. Correlation and path coefficient studies for yield and yield attributing characters in cowpea [*Vigna unguiculata* (L.) Walp.]. *Recent Horticulture* 1(1), 61–67.
- Narayanakutty, C., Mili, R., Jaikumaran, U., 2003a. Variability and genetic divergence in vegetable cowpea. *Journal of Maharashtra Agricultural Universities* 28 (1), 26–29.
- Narayanakutty, C., Mili, R., Jaikumaran, U., 2003b. Correlation and path coefficient analysis in vegetable cowpea. [*Vigna unguiculata* (L.) Walp.]. *Indian. Journal of Horticulture* 60(3), 257–261.
- Pal, A.K., Maurya, A.N., Singh, B., Ram D., Kumar, S., 2003. Genetic variability, heritability and genetic advance in cowpea [*Vigna unguiculata* (L.) Walp.]. *Orissa Journal of Horticulture* 31(1), 94–97.
- Panase, V.G., 1957. Genetics of quantitative characters in relation to plant breeding. *Indian Journal of Genetics* 17, 318–328.
- Patel, U.V., Parmar, V.K., Patel, P.B., Malviya, A.V., 2016. Correlation and path analysis study in cowpea *Vigna unguiculata* (L.). *International Journal of Science, Environment and Technology* 5(6), 3897–3904.
- Patil, B.L., Hegde, V.S., Saliath, P.M., 2003. Studies on genetic divergence over stress and non stress environment in mungbean. *Indian Journal Genetics and Plant Breeding* 63, 77–76.
- Rajaravindran, R., Das, L.D.V., 1997. Variability, heritability and genetic advance in vegetable cowpea. *Madras Agricultural Journal* 84(11-12), 702–703.
- Ram, D., Singh, K.P., 1997. Variation and character association studies in cowpea (*Vigna unguiculata* L.). *Horticultural Journal* 10(2), 93–99.
- Reddy, R.C., Sekhar, M.R., Reddy, K.R., 1994. Character association and path coefficient analysis in green gram (*Vigna radiate* (L.) Wilczek). *Annals of Agricultural Research* 15(4), 423–427.
- Resmi, P.S., Celine, V.A., Abdulvhab, M., 2004. Genetic variability in yard long bean [*Vigna unguiculata* subsp. *sesquipedalis* (L.) veridcourt.]. *Legume Research* 27(4), 296–298.
- Sawarkar, N.W., Poshia, V.K., Pithia, M.S., Dhameliya, H.R., 1999. Genetics of pod yield and its components in cowpea. [*Vigna unguiculata* (L.) Walp.]. *G.A.U. Research Journal* 25(1), 100–102.
- Searle, S.R., 1965. The value of indirect selection. *Biometrics* 21, 682–707.
- Sreekumar, K., Inasi, K.A., Alice, A., Nair, R.R., 1996. Genetic variability, heritability and correlation studies in vegetable cowpea (*Vigna unguiculata* var. *sesquipedalis*). *South Indian Horticulture* 44(1&2), 15–18.
- Tewari, A.K., Gautam, N.C., 1989. Correlation and path coefficient analysis in cowpea [*Vigna unguiculata* (L.) Walp.]. *Indian Journal of Horticulture* 46(4), 516–521.
- Vardhan, P.N.H., Savithramma, D.L., 1998. Variability, character association, path analysis and assessment of quality parameters in cowpea (*Vigna unguiculata*) germplasm for vegetable traits. *ACIAR Food legume News letter*, 79.
- Wright, S., 1921. Correlation and causation. *Journal of Agricultural Research* 20, 557–585.

