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## Correlation and path analysis in clusterbean (*Cyamopsis tetragonoloba* (L.) Taub)

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**Abstract**

Correlation studies with fifty one genotypes in cluster bean conducted during summer season revealed that pod yield per plant exhibited highly significant and positive association with pod yield per hectare, pod length, pod weight, number of pods per plant, number of clusters per plant, pod girth, number of branches per plant, plant height, gum content, number of pods per cluster, number of seeds per pod, protein content and fibre content. These characters are to be given due consideration in selection for yield improvement of the crop. Path analysis of fifty one genotypes revealed that maximum positive direct effect on pod yield per plant was exhibited through pod weight followed by number of pods per plant.

**Keywords:** Correlation, path analysis, yield, yield parameters, cluster bean genotypes

**Introduction**

Cluster bean (*Cyamopsis tetragonoloba* (L.) Taub) crop with a chromosome number of  $2n=2x=14$  which is popularly known as guar, chavlikayi, guari, khutti. It's a self-pollinated crop belongs to the family Fabaceae. Cluster bean is mainly cultivated for food, feed and fodder. Its young pods are used as vegetables, which also known for cheap source of energy (16 Kcal), protein (3.2g), fat (1.4 g), carbohydrate(10.8 g), vitamin A (65.3 IU), vitamin C (49 mg), calcium (57 mg) and iron (4.5 mg) for every 100 g of edible portion. India is the major guar producer accounting for 80% of the world's production. In India, guar is being grown mainly in arid and semiarid regions of North Western states of Rajasthan, Gujarat, Haryana, Punjab, parts of Uttar Pradesh, Madhya Pradesh and Tamil Nadu covering about 3.34 million hectares with a production of 0.4 million tonnes of guar seed. Rajasthan occupies the largest area under guar cultivation (82.1%), followed by Haryana (8.6%), Gujarat (8.3%) and Punjab (1%) which in turn produced 64, 22, 12 and 2% guar seeds, respectively (Pathak *et al.*, 2010) [11]. Guar is a mainly grown for its tender fruits for use as vegetable. It is also used as a nutritious fodder for livestock. Mucilaginous seed flour is used for making guar gum (galactomannan) utilized in textile, paper, cosmetic and oil industries throughout the world and is a useful absorbent for explosives (Smith, 1976) [19]. The correlation analysis is a biometrical technique to find out the nature and degree of association between various morphological traits indicating yield, while path coefficient analysis splits the correlation coefficient into direct and indirect effects so as to measure the relative contribution of each variable towards the yield (Al-jibouri *et al.*, 1958) [1].

**Materials and Methods**

The present investigation was carried out at College of Horticulture, Rajendranagar, Sri Konda Laxman Telangana State Horticultural University, Hyderabad with 51 genotypes of Cluster bean during Summer, 2017. The experiment was laid out in randomized completely block design with three replications. Each genotype was sown at 60cm x 15 cm row to row and plant to plant distance, respectively. Recommended fertilizer dose and cultural practices including need-based plant protection measures were followed to raise a good crop. Observations from five randomly selected plants of each genotype in each replication were recorded on sixteen quantitative traits viz. plant height (cm), number of branches per plant, days to first flowering, days to 50 % flowering, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length (cm), pod width (mm), pod weight(g), pod yield per plant (g), pod yield per hectare (q/ha), protein content (%), gum content(%) and fibre content(%). To determine the degree of association of characters with yield and also among the yield components, the correlation coefficients were calculated. Both genotypic and phenotypic coefficients of correlation between two characters were determined by using the variance and covariance components as suggested by Al-Jibouri *et al.* (1958) [1].

Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as suggested by Wright (1921)<sup>[21]</sup> and illustrated by Dewey and Lu (1959)<sup>[4]</sup> by partitioning the simple correlation coefficients into direct and indirect effects.

## Results and discussions

Yield, being a complex character is governed by a large number of genes. The influence of each character on yield could be known through correlation studies with a view to determine the extent and nature of relationships prevailing among yield and yield attributing characters. The present investigation was carried out to study the association of different characters on yield and yield attributing traits in cluster bean both at phenotypic levels and genotypic levels.

In general, it is evident from the data recorded that genotypic correlation was higher than the phenotypic correlation indicating strong inherent association of characters, and a less influence of environmental factors and relative stability of the genotypes. The phenotypic correlation (P) and genotypic correlation (G) coefficients were worked out for sixteen characters in 51 cluster bean genotypes and the data is presented in Tables 1 and 2.

Plant height exhibited positive and significant correlation with number of branches per plant (0.4295P, 0.3876G), number of clusters per plant (0.4110P, 0.5833G), number of pods per cluster (0.6811P, 0.7237G), number of pods per plant (0.4156P, 0.3494G), pod length (0.4903P, 0.6312G), pod girth (0.5923P, 0.5729G), pod weight (0.4364P, 0.3967G), number of seeds per pod (0.5689P, 0.5183G), pod yield per hectare (0.5573P, 0.5201G), protein content (0.2807P, 0.1814G), gum content (0.2803P, 0.2179G), fibre content (0.1098P, 0.0371G), pod yield per plant (0.5573P, 0.5202G) and days to 50 per cent flowering (0.0059P) at 5% level of significance. These results are confirmed for pod length, number of seeds per pod and number of pods per cluster by Rai and Dharmatti (2014)<sup>[14]</sup>; for pod yield per plant and gum content by Malaghan *et al.* (2014)<sup>[9]</sup>. This character also exhibited negative and significant correlation with days to first flowering (-0.0702P, -0.4172G) and days to 50 per cent flowering (-0.4622G). These results are similar for days to 50% flowering by Malaghan *et al.* (2014)<sup>[9]</sup>. Number of branches exhibited positive and significant correlation with number of clusters per plant (0.4076P, 0.5763G), number of pods per cluster (0.5257P, 0.5417G), number of pods per plant (0.5666P, 0.5129G), pod length (0.4498P, 0.5777G), pod girth (0.4168P, 0.3465G), pod weight (0.3847P, 0.3307G), number of seeds per pod (0.2744P, 0.1429G), pod yield per hectare (0.6009P, 0.5580G), protein content (0.1955P, 0.0780G), gum content (0.3365P, 0.2724G), fibre content (0.1310P, 0.0600G), pod yield per plant (0.6005P, 0.5576G), days to flowering (0.1160P) and plant height (0.4295P, 0.3876G) at 5% level of significance. Similar results are noticed for number of clusters per plant, number of pods per cluster and pod yield per plant by Manivannan and Anandakumar (2013)<sup>[8]</sup> for number of pods per plant by Anandi and Oommen (2010)<sup>[3]</sup>. This character also exhibited negative and significant correlation with days to first flowering (-0.0162P, -0.3171G), days to 50% flowering (-0.2982G). Similar results are reported by Manivannan and Anandakumar (2013)<sup>[8]</sup>. Days to first flowering exhibited positive and significant correlation with days to 50% flowering (0.5665P, 0.0165G). Similar results are reported by Malaghan *et al.* (2014)<sup>[9]</sup>. This character also exhibited negative and significant correlation with number of clusters per plant (-0.2603P, -0.1027G), number of pods per cluster (-0.1526P, -0.2990G), number of pods per plant (-0.0349P, -0.4132G), pod length (-0.3478P, -0.2903G), pod girth (-0.0678P, -0.4505G), pod weight (-0.0956P, -0.3851G), number of seeds per pod (0.0772P, -0.3862G), pod yield per hectare (-0.1253P, -0.4984G), protein content (0.2332P, -0.0373G), gum content (-0.0814P, -0.3799G), fibre content (-0.0166G) and pod yield per plant (-

0.1253P, -0.4987G) at 5% level of significance. Days to 50% flowering exhibited negative and significant correlation with number of clusters per plant (-0.2772P, -0.1071G), number of pods per cluster (-0.0332P, -0.1835G), number of pods per plant (-0.5200G), pod length (-0.3659P, -0.3562G), pod girth (-0.4146G), pod weight (-0.3741G), number of seeds per pod (-0.4909G), pod yield per hectare (-0.0518P, -0.5719G), protein content (-0.0674G), gum content (-0.3009G), fibre content (-0.0063G) and pod yield per plant (-0.5721G). Similar results are observed for pod length by Rai and Dharmatti (2014)<sup>[14]</sup>. This character also exhibited positive and significant correlation with number of pods per plant (0.0153P), pod girth (0.0585P, -0.4146G), pod weight (0.0015P), number of seeds per pod (0.1385P), pod yield per hectare (-0.0518P), protein content (0.2146P), gum content (0.0535P), fibre content (0.1804P) and pod yield per plant (0.0517P) at 5% LOS.

Number of clusters per plant exhibited positive and significant correlation with number of pods per cluster (0.5471P, 0.6172G), number of pods per plant (0.6219P, 0.8336G), pod length (0.5381P, 0.5233G), pod girth (0.2802P, 0.4207G), pod weight (0.2199P, 0.3225G), number of seeds per pod (0.2872P, 0.5181G), pod yield per hectare (0.5537P, 0.7313G), gum content (0.3323P, 0.4537G), pod yield per plant (0.5337P, 0.7312G), plant height (0.4110P, 0.5833G) and number of branches per plant (0.4076P, 0.5763G) at 5% LOS. Similar results are confirmed for number of pods per cluster, pod yield per plant and plant height by Saint *et al.*, 2010<sup>[15]</sup> and Girish *et al.*, 2012<sup>[5]</sup>; for gum content by Malaghan *et al.* (2014)<sup>[9]</sup>. This character also exhibited negative and significant correlation with protein content (-0.0674P, -0.0470G), fibre content (-0.2288P, -0.1796G), days to first flowering (-0.2603P, -0.1027G) and days to 50% flowering (-0.2772P, -0.1071G). Similar results are confirmed with Arumugarangarajan *et al.* (2000)<sup>[2]</sup> for days to 50 per cent flowering.

Number of pods per cluster exhibited positive and significant correlation with number of pods per plant (0.5595P, 0.5730G), pod length (0.7152P, 0.7647G), pod girth (0.6878P, 0.710G), pod weight (0.5547P, 0.5552G), number of seeds per pod (0.4188P, 0.4343G), pod yield per hectare (0.7495P, 0.7698G), protein content (0.3512P, 0.3457G), fibre content (0.0616P, 0.0413G), gum content (0.4672P, 0.4659G), pod yield per plant (0.7494P, 0.7697G), plant height (0.6811P, 0.7237G), number of branches per plant (0.5257P, 0.5417G) and number of clusters per plant (0.5471P, 0.6172G) at 5% LOS. These results are similar for earlier findings of pod yield per plant, number of clusters per plant, plant height by Saini *et al.* (2010)<sup>[15]</sup>, Girish *et al.* (2012)<sup>[5]</sup> and for protein and gum content by Malaghan *et al.* (2014)<sup>[9]</sup>. This character also exhibited negative and significant correlation with days to first flowering and days to 50 per cent flowering. Similar results are reported for days to 50% flowering by Arumugarangarajan *et al.* (2000)<sup>[2]</sup>. Number of pods per plant exhibited positive and significant correlation with pod length (0.4009P, 0.5298G), pod girth (0.3943P, 0.3161G), pod weight (0.2515P, 0.1729G), number of seeds per pod (0.3068P, 0.1621G), pod yield per hectare (0.7670P, 0.7373G), gum content (0.3691P, 0.2998G), pod yield per plant (0.7669P, 0.7372G), plant height (0.4156P, 0.3494G), number of branches per plant (0.5666P, 0.5129G), number of clusters per plant (0.6219P, 0.8336G), number of pods per cluster (0.5595P, 0.5730G), protein content (0.1278P) and fibre content (0.0773P) at 5% LOS. For pod yield per plant similar results were reported by Malaghan *et al.* (2014)<sup>[9]</sup>. This character also exhibited negative and significant correlation with protein content (-0.0177G), fibre content (-0.008G), days to first flowering (-0.0349P, -0.4132G) and days to 50% flowering (-0.5200G) at 5% LOS. Pod length (cm) exhibited positive and significant correlation with pod girth (0.6517P, 0.7969G), pod weight (0.5985P, 0.6979G), number of seeds per pod (0.3118P, 0.4942G), pod yield per hectare (0.6774P, 0.8190G), gum content

(0.3954P, 0.4847G), pod yield per plant (0.6773P, 0.8189G), protein content(0.2178P, 0.3336G), fibre content(0.0481P, 0.1017 G), plant height (0.4903P, 0.6312G), number of branches per plant (0.4498P, 0.5777G), number of clusters per plant (0.5381P, 0.5233G), number of pods per cluster (0.7152P, 0.7647G), number of pods per plant (0.4009P, 0.5298G) at 5 % LOS. These results are similar to findings for plant height, number of pods per cluster and number of seeds per pod by Rai and Dharmatti (2014) [14]. This character also exhibited negative and significant correlation with days to first flowering (-0.3478P, -0.2903G) and days to 50% flowering (-0.3659P, -0.3562G). Pod girth (mm) exhibited positive and significant correlation with pod weight(0.5874P, 0.559G), number of seeds per pod (0.3184P, 0.2002G), pod yield per hectare(0.6461P, 0.6105G), gum content (0.4973P, 0.4537G), pod yield per plant (0.6464P, 0.6107G), protein content(0.3930P, 0.3100G), fibre content(0.0869P), plant height (0.5923P, 0.5729G), number of branches per plant (0.4168P, 0.3465G), number of clusters per plant (0.2802P, 0.4207G), number of pods per cluster (0.6848P, 0.7102P), number of pods per plant (0.3943P, 0.3161G), pod length (0.6517P, 0.7969G) at 5 % LOS. Similar results are reported for pod length by Rai and Dharmatti. (2014) [14] for pod yield per plant and plant height by Malaghan *et al.* (2014) [9]. This character also exhibited negative and significant correlation with days to first flowering (-0.0678P, -0.4505G) and days to 50% flowering (-0.4146G) and crude fiber content (-0.0128G) at genotypic level. Similar results are reported for days to 50 per cent flowering by pan *et al.* (2004) [10] in dolichos bean. Pod weight (g) exhibited positive and significant correlation with number of seeds per pod (0.3871P, 0.3107G), pod yield per hectare (0.8000P, 0.7846G), gum content (0.4904P, 0.4511G), pod yield per plant (0.8001P, 0.7847G), protein content(0.3650P, 0.2955G), fibre content(0.2588P), plant height (0.4364P, 0.3967G), number of branches per plant (0.3847P, 0.3307G), number of clusters per plant (0.2199P, 0.3225G), number of pods per cluster (0.5547P, 0.5552G), number of pods per plant (0.2515P, 0.1729G), pod length (0.5985P, 0.6979G) and pod girth (0.5874P, 0.5559G) at 5% LOS. Similar results are reported for pod yield per plant by Malaghan *et al.* (2014) [9]. This character also exhibited negative and significant correlation with days to first flowering (-0.0956P, -0.3851G) and days to 50% flowering (-0.3741G), protein content (-0.2111G) at genotypic level. Number of seeds per pod exhibited positive and significant correlation with pod yield per hectare(0.4497P, 0.6), gum content (0.3149P, 0.2197G), pod yield per plant 0.4496P, 0.3573G), protein content(0.1654P), fibre content(0.2957P, 0.2192 G), plant height (0.5689P, 0.5183G), number of branches per plant (0.2744P, 0.1429G), number of clusters per plant (0.2872P, 0.5181G), number of pods per cluster (0.4188P, 0.4243G), number of pods per plant (0.3068P, 0.1621G), pod length (0.3118P, 0.4942G), pod girth (0.3184P, 0.2002G) and pod weight(0.3871P, 0.3107G) at 5 % LOS. Similar results are reported by earlier findings for pod yield per plant by Anandhi and Oomen (2010) [3] and for plant height, pod length and pod girth by Rai and Dharmatti (2014) [14]. This character also exhibited negative and significant correlation with days to first flowering (-0.3862G) and days to 50% flowering (-0.4909G) and protein content (-0.300G) at genotypic level Similar results for days to 50% flowering by earlier findings of Rai and Dharmatti (2014) [14]. Pod yield per hectare (q/ha) exhibited positive and significant correlation with gum content (0.5484P, 0.5067G), pod yield per plant (1.000P, 1.000G), protein content(0.3401P, 0.2462G), fibre content(0.1991P, 0.1352G), plant height (0.5573P, 0.5201G), number of branches per plant (0.6009P, 0.5580G), number of clusters per plant (0.5537P, 0.7313G), number of pods per cluster (0.7495P, 0.7698G), number of pods per plant(0.7670P, 0.7373G), pod length (0.6774P, 0.8190G), pod girth (0.6461P, 0.6105G), pod weight (0.8000P, 0.7846G) and number of seeds per pod(0.4497P, 0.3574G)at 5 % LOS. This

character also exhibited negative and significant correlation with days to first flowering (-0.1253P, -0.4984G) and days to 50 per cent flowering (-0.0518P, -0.5719G).

Protein content (%) exhibited positive and significant correlation with gum content (0.2651P, 0.1781G), fibre content(0.2865P, 0.2194G), pod yield per plant (0.3403P, 0.2465G), plant height (0.2807P, 0.1814G), number of branches per plant (0.1955P, 0.0780G), number of clusters per plant(0.0470G), number of pods per cluster (0.3512P, 0.3457G), pod length (0.2178P, 0.3336G), pod girth (0.3930GP, 0.3100G), pod weight (0.3650P, 0.2955G), number of seeds per pod (0.1654P) and pod yield per hectare (0.3401P, 0.2462G)at 5 % LOS. Similar results are reported for pod girth Girish *et al.* (2012) [5], for number of pods per plant Malaghan *et al.* (2014) [9]. This character also exhibited negative and significant correlation with days to first flowering (-0.0373G), days to 50% flowering (-0.2146P, -0.0674G), number of pods per plant (-0.0177G) and number of seeds per pod (-0.0300G).

In respect of gum content (%), positive and significant correlation with pod yield per plant (0.5487P, 0.5068G), plant height (0.2803P, 0.2179G), number of branches per plant (0.3365P, 0.2724G), number of clusters per plant (0.3323P, 0.4537G), number of pods per cluster (0.4672P, 0.4659G), number of pods per plant (0.3691P, 0.2998G), pod length (0.3954P, 0.4847G), pod girth (0.4973P, 0.4537G), pod weight (0.4904P, 0.4511G), number of seeds per pod (0.3149P, 0.2197G), pod yield per hectare (0.5487P, 0.5067G) and protein content (0.2651P, 0.1781G). Similar results are reported for plant height by Girish *et al.* (2012) [5]. This character exhibited negative and significant correlation with fibre content (-0.1132P, -0.1896G), days to first flowering (-0.0814P, 0.3799G) and days to 50 per cent flowering (-0.3009G). Fibre content (%) exhibited positive and significant correlation with pod yield per plant (0.1989P, 0.1349G), plant height (0.1098P, 0.0371G), number of branches per plant (0.1310P, 0.0600G), number of pods per cluster (0.0616P, 0.0413G), number of pods per plant (0.0773P), pod length (0.0481P, 0.1017G), pod girth (0.0869P, 0.0128G), pod weight (0.2588P, 0.2111G), number of seeds per pod (0.2957P, 0.2192G), pod yield per hectare (0.1991P, 0.1352G) and protein content (0.2865P, 0.2194) at 5 % LOS. Similar results were reported for plant height by Kapoor *et al.* (2014) [7]. This character also exhibited negative and significant correlation with days to first flowering (-0.0166G), days to 50 per cent flowering (-0.0063G), number of clusters per plant (-0.2288P, -0.1796G), number of pods per plant (-0.0082G) and gum content (-0.1132P, -0.1896G). Pod yield per plant exhibited positive and significant correlation with plant height (0.5573P, 0.5202G), number of branches per plant (0.6005P, 0.5576), number of clusters per plant (0.5537, 0.7312G), number of pods per cluster (0.7494, 0.7697), number of pods per plant (0.7669P, 0.7372), pod length (0.6773, 0.8189G), pod girth (0.6464, 0.6107G), pod weight(0.8001P, 0.7847G), pod yield per hectare (1.000P, 1.000G), protein content (0.3403, P, 0.2465G), gum content (0.5487, 0.5068G), fibre content (0.1989P, 0.1349) at 5 % LOS. These results are in line with the findings of various studies conducted in cluster bean by Manivannan and Anandakumar (2013) [8] for number of branches per plant, clusters per plant, Arumugarangarajan *et al.* (2000) [2] for clusters per plant and number of seeds per pod, Vir and Singh (2015) [20], Saini *et al.* (2010) [15], Singh *et al.* (2005) [18], Singh *et al.* (2002) [17], Singh *et al.* (2001), number of seeds per pod, Patil. (2014) [12] for clusters per plant and number of seeds per pod, Ibrahim *et al.* (2013) [6], Shah *et al.* (2000) [16] and for number of clusters per plant, Singh *et al.*, 2004 for clusters per plant and number of seeds per pod. This character also exhibited negative and significant correlation with days to first flowering (-0.1253P, -0.4987G) and days to 50% flowering (-0.5721G). Similar results are reported for days to 50 % flowering by Malaghan *et al.*, 2014 [9].

**Table 1:** Phenotypic (P) correlation coefficients among yield and yield attributes in 51 genotypes of cluster bean

Characters	Plant height (cm)	No. of branches per plant	Days to first flowering	Days to 50% flowering	Number of clusters per plant	Number of pods per plant	Number of Pods per plant	Pod Length (cm)	Pod girth (mm)	Pod weight (g)	Number of seeds per pod	Pod yield per hectare (q/ha)	Protein content (%)	Gum content (%)	Fibre content (%)	Pod yield per plant (g)
Plant height (cm)	1.0000	0.4295**	-0.0702	0.0059	0.4110**	0.6811	0.4156**	0.4903**	0.5923**	0.4364**	0.5689**	0.5573**	0.2807**	0.2803**	0.1098**	0.5573
Number of branches per plant		1.0000	0.0162	0.1160	0.4076**	0.5257**	0.5666**	0.4498**	0.4168**	0.3847**	0.2744**	0.6009**	0.1955*	0.3365**	0.1310	0.6005
Days to first flowering			1.0000	0.5665**	-0.2603**	-0.1526	-0.0349	-0.3478**	-0.0678	-0.0956	0.0772	-0.1253	0.2332**	-0.0814	0.1420	-0.1253
Days to 50% flowering				1.0000	-0.2772**	-0.0332	0.0153	-0.3659**	0.0585	0.0015	0.1385	-0.0518	0.1961*	0.0535	0.1804*	0.0517
Number of clusters per plant					1.0000	0.5471**	0.6219**	0.5381**	0.2802**	0.2199**	0.2872**	0.5537**	-0.0674	0.3323**	-0.2288**	0.5537
Number of pods per cluster						1.0000	0.5595**	0.7152**	0.6878**	0.5547**	0.4188**	0.7495**	0.3512**	0.4672**	0.0616	0.7494
Number of pods per plant							1.0000	0.4009**	0.3943**	0.2515**	0.3068**	0.7670**	0.1278**	0.3691**	0.0773	0.7669
Pod length (cm)								1.0000	0.6517**	0.5985**	0.3118**	0.6774**	0.2178**	0.3954**	0.0481	0.6773
Pod girth (mm)									1.0000	0.5874**	0.3184**	0.6461**	0.3930**	0.4973**	0.0869	0.6464
Pod weight (g)										1.0000	0.3871**	0.8000**	0.3650**	0.4904**	0.2588**	0.8001
Number of seeds per pod											1.0000	0.4497**	0.1654**	0.3149**	0.2957**	0.4496
Pod yield per hectare (q/ha)												1.0000	0.3401**	0.5487**	0.1991*	1.0000
Protein content (%)													1.0000	0.2651**	0.2865**	0.3403
Gum content (%)														1.0000	-0.1132	0.5487
Fibre content (%)															1.0000	0.1989

\*Significant at 5 per cent level; \*\* Significant at 1 per cent level

**Table 2:** Genotypic (G) correlation coefficients among yield and yield attributes in 51 genotypes of cluster bean

Characters	Plant Height (cm)	No. of Branches per plant	Days to First flowering	Days to 50% flowering	Number of Clusters per plant	Number of Pods per plant	Number of Pods per plant	Pod length (cm)	Pod Girth (mm)	Pod Weight (g)	Number of Seeds per pod	Pod yield per hectare (q/ha)	Protein Content (%)	Gum Content (%)	Fibre Content (%)	Pod yield per plant (gm)
Plant height (cm)	1.0000	0.3876	-0.4172	-0.4622	0.5833	0.7237	0.3494	0.6312	0.5729	0.3967	0.5183	0.5201	0.1814	0.2179	0.0371	0.5202
Number of branches per plant		1.0000	-0.3171	-0.2982	0.5763	0.5417	0.5129	0.5777	0.3465	0.3307	0.1429	0.5580	0.0780	0.2724	0.0600	0.5576
Days to first flowering			1.0000	0.0165	-0.1027	-0.2990	-0.4132	-0.2903	-0.4505	-0.3851	-0.3862	-0.4984	-0.0373	-0.3799	-0.0166	-0.4987
Days to 50% flowering				1.0000	-0.1071	-0.1835	-0.5200	-0.3562	-0.4146	-0.3741	-0.4909	-0.5719	-0.2146	-0.3009	-0.0063	-0.5721
Number of clusters per plant					1.0000	0.6172	0.8336	0.5233	0.4207	0.3225	0.5181	0.7313	0.0470	0.4537	-0.1796	0.7312
Number of pods per cluster						1.0000	0.5730	0.7647	0.7102	0.5552	0.4343	0.7698	0.3457	0.4659	0.0413	0.7697
Number of pods per plant							1.0000	0.5298	0.3161	0.1729	0.1621	0.7373	-0.0177	0.2998	-0.0082	0.7372
Pod length (cm)								1.0000	0.7969	0.6979	0.4942	0.8190	0.3336	0.4847	0.1017	0.8189
Pod girth (mm)									1.0000	0.5559	0.2002	0.6105	0.3100	0.4537	0.0128	0.6107
Pod weight (g)										1.0000	0.3107	0.7846	0.2955	0.4511	0.2111	0.7847
Number of seeds per pod											1.0000	0.3574	-0.0300	0.2197	0.2192	0.3573
Pod yield per hectare (q/ha)												1.0000	0.2462	0.5067	0.1352	1.0000
Protein content (%)													1.0000	0.1781	0.2194	0.2465
Gum content (%)														1.0000	-0.1896	0.5068
Fibre content (%)															1.0000	0.1349

\*Significant at 5 per cent level; \*\* Significant at 1 per cent level

**Path analysis**

Path analysis was carried out at phenotypic and genotypic levels considering fruit yield as dependent character and its attributes as independent characters *viz.*, plant height, number of branches per plant, days to first flowering, days to 50 per cent flowering, number of clusters per plant, number of pods per plant, number of pods per plant, pod length, pod girth, pod weight, number of seeds per pod, pod yield per hectare, protein content, gum content and fibre content. Each component has two path actions *viz.*, direct effect on yield and indirect effect through components which are not revealed by correlation studies. The results are presented in Table 3 and 4. Plant height exhibited negligible negative direct effect (-0.0001G) on pod yield per plant at genotypic level. These results are similar with findings of Arumugarangarajan *et al.* (2000) [2] and Manivannan and Anandakumar (2013) [8]. Number of branches per plant showed negligible positive direct effect (0.0006P, 0.0006G) on pod yield per plant at both phenotypic and genotypic level. Days to first flowering reported negligible negative direct effect (-0.0003G) on pod yield per plant at genotypic level. This trait reported negligible positive direct effect (0.0001P) at phenotypic level. Days to 50 per cent flowering exhibited negligible negative direct effect (-0.0002G) on pod yield per plant at genotypic level. This trait exhibited negligible positive direct effect (0.0003P) at phenotypic level. These results were similar findings with Manivannan and Anandakumar (2013) [8] and Patil (2014) [12] for phenotypic level.

At genotypic level, number of clusters per plant observed negligible positive direct effect (0.0001G) on pod yield per plant. This trait observed negligible positive direct effect (0.0004P) on pod yield per plant at phenotypic level. Similar results were findings with Singh *et al.* (2002) [17] and Patil (2014) [12]. Number of pods per cluster reported negligible positive direct effect (0.0003G) on pod yield per plant at genotypic level. These results are similar findings with Patil (2014) [12]. Number of pods per cluster reported negligible negative direct effect (-0.0004P) on pod yield per plant at genotypic level.

Number of pods per plant showed low positive direct effect on pod yield per plant (0.0029G) at genotypic level. At phenotypic level, this trait exhibited low direct negative effect (-0.0010) on fruit yield per plant. Similar results are obtained by Raghuprakash *et al.* (2009) [13]. At genotypic level and phenotypic level, pod length recorded negligible negative direct effect (-0.0005P, -0.0003G) on pod yield per plant at both phenotypic and genotypic levels. Similar results are obtained by Manivannan and Anandakumar (2013) [8] and Patil (2014) [12]. Pod girth reported negligible positive direct effect (0.0008P, 0.0003G) on pod yield per plant at both phenotypic and genotypic level. Similar results are obtained by Patil (2014) [12]. Pod weight showed negligible positive direct effect on fruit yield per plant (0.0033G) at genotypic level. Similar results are reported by Malaghan *et al.* (2014) [9]. At phenotypic level, this trait exhibited negligible direct negative effect (-0.0008P) on pod yield per plant. At genotypic level, number of seeds per pod recorded very negligible positive direct effect (0.0001) on pod yield per plant. Similar results are obtained by Singh *et al.*, 2002 [17], Ibrahim *et al.*, 2012 [6], Manivannan and Anandakumar (2013) [8] and Patil (2014) [12]. At phenotypic level, negligible negative direct effect was exhibited (-0.0002P) on pod yield per plant. Pod yield per hectare had high positive direct effect on pod yield per plant (1.0018P, 0.9950G) at phenotypic and genotypic levels respectively.

Protein content recorded negligible positive direct effect on pod yield per plant (0.0006G) at genotypic level. Similar results were obtained by Kapoor (2014) [7]. At phenotypic level, this character showed negligible positive direct effect (0.0002P) on pod yield per plant. These results are similar with Kapoor (2014) [7]. Gum content recorded negligible negative direct effect on pod yield per plant (-0.0001G) at genotypic level. At phenotypic level, it showed negligible negative direct effect (-0.0002P) on pod yield per plant. Fibre content recorded negligible negative direct effect on pod yield per plant (-0.0004) at genotypic level. At phenotypic level, it showed negligible negative direct effect (-0.0003) on pod yield per plant.

**Table 3:** Phenotypic (P) path coefficient analysis indicating direct and indirect effects of components characters on fruit yield in 51 genotypes of cluster bean

Characters	Plant height (cm)	No. of branches per plant	Days to first flowering	Days to 50% flowering	Number of clusters per plant	Number of pods per cluster	Number of pods per plant	Pod Length (cm)	Pod Girth (mm)	Pod Weight (g)	Number of seeds per pod	Pod yield per hectare (q)	Protein Content (mg/g)	Gum content (%)	Fibre Content (%)	Pod yield per plant (g)
Plant height (cm)	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5202
Number of branches per plant	-0.0002	0.0006	0.0002	0.0002	-0.0003	-0.0003	-0.0003	-0.0003	-0.0002	-0.0002	-0.0001	-0.0003	0.0000	-0.0002	0.0000	0.5576
Days to first flowering	0.0001	0.0001	-0.0003	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0000	0.0001	0.0000	-0.4987
Days to 50% flowering	0.0001	0.0001	0.0000	-0.0002	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0000	-0.5721
Number of clusters per plant	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0000	0.0001	0.0001	0.7312
Number of pods per cluster	0.0002	0.0002	-0.0001	-0.0001	0.0002	0.0003	0.0002	0.0003	0.0002	0.0002	0.0001	0.0003	0.0001	0.0002	0.0000	0.7697
Number of pods per plant	0.0010	0.0015	-0.0012	-0.0015	0.0024	0.0017	0.0029	0.0015	0.0009	0.0005	0.0005	0.0022	-0.0001	0.0009	0.0000	0.7372
Pod length(cm)	-0.0002	-0.0002	0.0001	0.0001	-0.0002	-0.0003	-0.0002	-0.0003	-0.0003	-0.0002	-0.0002	-0.0003	-0.0001	-0.0002	0.0000	0.8189
pod girth(mm)	0.0002	0.0001	-0.0001	-0.0001	0.0001	0.0002	0.0001	0.0002	0.0003	0.0002	0.0001	0.0002	0.0001	0.0001	0.0000	0.6107
pod weight(g)	0.0001	0.0011	-0.0013	-0.0012	0.0011	0.0018	0.0006	0.0023	0.0018	0.0033	0.0010	0.0026	0.0010	0.0015	0.0007	0.7847
Number of seeds per plant	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.3573
Pod yield per hectare(q/ha)	0.5175	0.5553	-0.4959	-0.5691	0.7277	0.7659	0.7336	0.8149	0.6075	0.7807	0.3556	0.9950	0.2450	0.5042	0.1345	1.0000
Protein content (%)	0.0001	0.0000	0.0000	-0.0001	0.0000	0.0002	0.0000	0.0002	0.0002	0.0002	0.0000	0.0001	0.0006	0.0001	0.0001	0.2465
Gum content (%)	0.0000	0.0000	0.0001	0.0000	-0.0001	-0.0001	0.0000	-0.0001	-0.0001	-0.0001	0.0000	-0.0001	0.0000	-0.0001	0.0000	0.5068
Fibre content (%)	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	-0.0001	-0.0001	-0.0001	-0.0001	0.0001	-0.0004	0.1349

Phenotypic Residual effect = 0.02; Diagonal (under lined) values indicate direct effects

**Table 4:** Genotypic (g) path coefficient analysis indicating direct and indirect effects of components characters on fruit yield in 51 genotypes of cluster bean

Characters	Plant Height (cm)	No. of branches per plant	Days to First flowering	Days to 50% flowering	Number of Clusters per plant	Number of pods per cluster	Number of pods per plant	Pod Length (cm)	Pod Girth (mm)	Pod Weight (g)	Number of seeds per pod	Pod yield Per hectare (q/ha)	Protein Content (mg/g)	Gum content (%)	Fibre Content (%)	Pod yield per plant (g)
Plant height (cm)	<u>0.0000</u>	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5573
Number of branches per plant	0.0002	<u>0.0006</u>	0.0000	-0.0001	-0.0002	-0.0003	-0.0003	-0.0003	-0.0002	-0.0002	-0.0002	-0.0003	-0.0001	-0.0002	-0.0001	0.6005
Days to first flowering	0.0000	0.0000	<u>0.0001</u>	-0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.1253
Days to 50% flowering	0.0000	0.0000	0.0001	<u>0.0003</u>	-0.0001	0.0000	0.0000	-0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	-0.0517
Number of clusters per plant	0.0002	0.0002	-0.0001	-0.0001	<u>0.0004</u>	0.0002	0.0002	0.0002	0.0001	0.0000	0.0001	0.0002	0.0000	0.0001	-0.0001	0.5537
Number of pods per cluster	0.0003	-0.0002	0.0001	0.0000	-0.0002	<u>-0.0004</u>	-0.0002	-0.0003	-0.0003	-0.0002	-0.0002	-0.0003	-0.0001	-0.0002	0.0000	0.7494
Number of pods per plant	0.0004	-0.0006	0.0000	0.0000	-0.0006	-0.0006	<u>-0.0010</u>	-0.0004	-0.0004	-0.0002	-0.0003	-0.0008	-0.0001	-0.0004	-0.0001	0.7669
Pod length(cm)	-0.0003	-0.0002	-0.0002	-0.0002	-0.0003	-0.0004	-0.0002	<u>-0.0005</u>	-0.0003	-0.0003	-0.0002	-0.0003	-0.0001	-0.0002	0.0000	0.6773
pod girth(mm)	0.0005	0.0003	-0.0001	0.0000	0.0002	0.0006	0.0003	0.0005	<u>0.0008</u>	0.0005	0.0003	0.0005	0.0003	0.0004	0.0001	0.6464
pod weight(g)	-0.0004	-0.0003	0.0001	0.0000	-0.0002	-0.0004	-0.0002	-0.0005	-0.0005	<u>-0.0008</u>	-0.0003	-0.0006	-0.0003	-0.0004	-0.0002	0.8001
Number of seeds per plant	-0.0001	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	-0.0001	-0.0001	-0.0001	<u>-0.0002</u>	-0.0001	0.0000	-0.0001	0.0000	0.4496
Pod yield per hectare(q/ha)	0.5583	0.6019	-0.1255	0.0519	0.5547	0.7508	0.7684	0.6786	0.6473	0.8015	0.4506	<u>1.0018</u>	0.3407	0.5497	0.1995	1.0000
Protein content (%)	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	<u>0.0002</u>	0.0001	0.0001	0.3403
Gum content (%)	-0.0001	-0.0001	0.0000	0.0000	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	<u>-0.0002</u>	0.0000	0.5487
Fibre content (%)	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	-0.0001	-0.0001	-0.0001	-0.0001	0.0000	<u>-0.0003</u>	0.1989

Genotypic Residual effect=0.08; Diagonal (under lined) values indicate direct effects

## Conclusions

Based on the simple correlation coefficients, the characters plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, pod girth, pod weight, pod yield per hectare, protein content, gum content and fibre content were found to possess significant and positive association with pod yield per plant. The results of the present study also revealed negative association of pod yield per plant with days to first flowering and days to 50 per cent flowering.

The genotypic correlation of pod length and pod weight with yield was high and significant, which is the valuable index for effective selection towards higher yield. Further, it indicated that plant height, number of branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, pod girth, pod weight, pod yield per hectare, protein content, gum content and fibre content had positive and significant association with pod yield and these characters are highly reliable components of pod yield and could very well be utilized as yield indicators, while exercising selection.

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