



# Studies on Genetic Variability and Character Association for Quantitative Traits of Garden Pea (*Pisum sativum* L.)

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## ABSTRACT

The field experiment was carried out in randomized block design repeating each genotype into 3 blocks at Agriculture Farm of Lovely Professional University, Jalandhar, Punjab, India during *rabi* season (November–March) of 2015–16. Variability in the breeding population is essential pre-requisite to improve yield, earliness, disease resistance, lodging resistance etc. and the study of correlation and path analysis help in formulating selection indices for yield improvement. Therefore, a study was carried out undertaken to assess the magnitude of genetic variability and character association in twenty four diverse genotypes of garden pea (*Pisum sativum* L.) based on eleven quantitative characters. Analysis Of Variance (ANOVA) showed the existence of wide variability among the genotypes for all the characters studied. Closer magnitude of genotypic and phenotypic variation also indicated the presence of considerable genetic variability for all characters. High proportion of GCV accompanied with high heritability (in broad sense) and high genetic gain/genetic advance as percentage of mean were recorded for the characters like days to 50% flowering, plant height, harvesting span, dry matter and pod yield. Significant positive genotypic and phenotypic correlations were observed among pod yield and days to 50% flowering, number of pods plant<sup>-1</sup> and number of seeds pod<sup>-1</sup>. These characters also had positive direct effect on pod yield. Hence, it can be concluded that selection is feasible for improvement of the characters studied under investigation.

**KEYWORDS:** Character association, genetic advance, heritability, pea, variability

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## 1. INTRODUCTION

Garden pea (*Pisum sativum* L.), a member of family Papilionaceae is an important vegetable crop of both temperate and subtropical areas of the world. The crop is grown for its green pods and dried seeds and is known for its superior quality protein like lysine content, the limiting amino acid in cereals (Monti, 1983). The green seeds are used as fresh, frozen or canned vegetables and the mature dry seeds are used as *dhal*. Green peas are high protein containing vegetable with a protein content of 6–7% on the fresh weight basis. In addition, pea remains are a nutritious feed for animals and therefore offer the poor farmer family with additional benefits. The acreage of vegetable pea in India is 540 tha with 5422'000 tof green pod production (Anonymous, 2018). It is a leading vegetable crop in the North-Western region of India comprising the states of Himachal Pradesh, Uttar Pradesh, Uttarakhand, Haryana, Punjab and Jammu & Kashmir. Peas fits well in the crop rotation component and in recent years, due to the need for intensive land utilization pea can be fitted as intercrop or mixed crop with grain crops. Short duration and early varieties of pea have the potential to provide premium returns to the farmers as they can fetch a better price and can be used for multi-cropping (Bahadur et al., 2006). The development of genotypes that offer a high genetic potential for seed yield or fodder yield is one of the fundamental directions for pea breeding (Singh et al., 2019).

Important achievements were obtained in pea cultivars through conventional breeding over the past 20 years. The possibility of improvement in any crop depends on genetic variation and new variation is fundamentally important for introduction of new traits in breeding programs (Holme et al., 2019). The evaluation of genetic variability is important to know the source of genes for a particular trait within the available germplasm (Singh et al., 2017, Singh et al., 2019, Aman et al., 2021). Moreover, relative values of phenotypic and genotypic variation coefficients give a reliable idea of the extent of variability in the population. The variability available in the population can be partitioned into heritable and non-heritable components (Begna, 2021). The higher the heritable variation, the greater will be the possibility of fixing the characters by selection methods (Sharma and Bora, 2013). Genotypic and different components of variance, heritability and genetic advance have been calculated for different yield characters in pea by several workers (Sureja and Sharma, 2000, Sharma et al., 2007, Choudhary et al., 2010, Kumar et al., 2013, Katoch et al., 2016, Bhardwaj et al., 2020).

Yield improvement cannot be solely achieved through direct selection because yield depends on various yield-contributing characters (Kumar et al., 2019). The efficiency of selection in any breeding program is enhanced with the knowledge

of the association of yield components. Correlation analysis helps to study the magnitude and direction of association of one character with another, while path coefficient analysis gives the direct and indirect contribution of independent variables on dependent variable (Rathi and Dhaka, 2007, Kalapchieva et al., 2021). It is important for plant breeders to find out which of the characters are correlated with yield to bring about genetic improvement in the crop. An improvement in yield of self-pollinated crops like garden pea is effected mainly through selection of genotypes with desirable characters from the diverse germplasm (Kumari et al., 2008). Keeping the facts in view, the present investigation was aimed at studying genetic variability and character association in the available germplasm of pea which may help to select suitable genotypes for commercial cultivation.

## 2. MATERIALS AND METHODS

A field experiment was conducted at Agriculture Farm of Lovely Professional University, Jalandhar, Punjab, India in a Randomized Block Design with three replications during *rabi* season (November–March, 2015–16). The experimental material comprised of twenty four diverse genotypes of garden pea, of which, PB- 01, PB- 89 and Wasundra are from PAU, Ludhiana, VRPE-14, VRPE-24, VRPE- 32 and VRPE- 58 are from IIVR, Varanasi and rest of the genotypes are the collection from Private Seed Company. The experimental site is situated at 31°22'31.81" North Latitude and 75°23'03.02" East longitude, with an average elevation and mean sea level of 252 m. The region falls under the Central plain agro climatic zone characterized by mild winters and moderate summers associated with high relative humidity during the rainy season. The maximum temperature (18°C–27°C) and minimum temperature (5°C–13°C) are favourable for the growth and development of garden pea. The soil of the experimental site was alkaline in reaction (pH=7.46) with 1.6% organic carbon. The crop was raised in 4×1.5 m<sup>2</sup> plot size. The seeds of vegetable pea genotypes were sown on November 2, 2015 at spacing of 30 cm between rows. Standard agronomic package of practices were adopted to raise a good crop. The crop was harvested in 3–4 pickings. The observations were recorded on five randomly selected plants for thirteen characters *viz.* growth, maturity and yield parameters including quality attributes such as dry matter and protein content. Finally, the obtained data were subjected to statistical analysis using OPSTAT software developed by CCS HAU, Hissar (Haryana).

Phenotypic and genotypic variances were calculated from the total variance by using the formula given by Burton (1952). The PCV and GCV were classified according to the procedure followed by Sivasubramanian and Madhavamenon (1973). Heritability ( $h^2$  percentage) was



calculated as suggested by Burton and Devane (1953). The heritability values were characterized as given by Johnson et al. (1955a). Genetic advance was estimated by formula described by Allard (1960). The range of genetic advance and as expected percent of mean are classified as followed by Johnson et al. (1955a). The coefficient of phenotypic and genotypic correlations among green yield and its component traits were calculated, respectively using the formula as suggested by Johnson et al. (1955b). Path co-efficient analysis was carried as recommended by Wright (1921) and further illustrated by Dewey and Lu (1959) for partitioning of genotypic correlations into direct and indirect effect upon green pod yield plant<sup>-1</sup>. The direct and indirect effects are rated as follows by Lenka and Mishra (1973).

### 3. RESULTS AND DISCUSSION

#### 3.1. Analysis of variance

The analysis of variance (Table 1) revealed that mean sum of squares due to genotypes showed highly significant differences in yield attributes viz., days to 50% flowering, plant height, number of branches plant<sup>-1</sup>, first fruiting

node, number of pods plant<sup>-1</sup>, number of seeds pod<sup>-1</sup>, days to marketable maturity, harvesting span, pod yield, and quality attributes viz., dry matter and protein, respectively. Findings of present study are in agreement with Ahmad et al. (2014), Singh et al. (2019) and Aman et al. (2021), who earlier reported significant variations in morphological characters of pea. Significant variations for yield and quality attributes of pea indicated the presence of genetic variability among the experimental material. However, carry forward of genotypes under study for biometric studies would be effective in selection of suitable genotype/variety, to determine selection criteria and breeding methods for improvement of garden pea (*Pisum sativum* L.) in particular geographical region.

#### 3.2. Estimates of variability components

Estimates of genetic parameters pertaining to genetic variability viz., population mean, range of variation, genotypic coefficient of variance (GCV) and phenotypic coefficient of variance (PCV), heritability (in broad sense) and genetic gain are given in Table 2 have been described below for all studied characters.

Table 1: Analysis of variance for eleven quantitative traits of garden pea

| Source | d.f. | Mean sum of squares   |                   |                                     |                     |                                 |                                |                             |                 |                |                                        |                                  |
|--------|------|-----------------------|-------------------|-------------------------------------|---------------------|---------------------------------|--------------------------------|-----------------------------|-----------------|----------------|----------------------------------------|----------------------------------|
|        |      | Days to 50% flowering | Plant height (cm) | No. of branches plant <sup>-1</sup> | First fruiting node | No. of pods plant <sup>-1</sup> | No. of seeds pod <sup>-1</sup> | Days to marketable maturity | Harvesting span | Dry matter (%) | Protein content (kg ha <sup>-1</sup> ) | Pod yield (kg ha <sup>-1</sup> ) |
| R      | 2    | 6.347                 | 3.580             | 0.455                               | 0.079               | 0.069                           | 0.077                          | 0.167                       | 4.667           | 0.049          | 6.1                                    | 2566.9                           |
| G      | 23   | 487.361**             | 636.450**         | 6.595**                             | 7.325**             | 10.263**                        | 2.423**                        | 320.522**                   | 217.485**       | 44.034**       | 2585.2**                               | 218198**                         |
| E      | 46   | 4.042                 | 3.041             | 0.532                               | 0.173               | 0.186                           | 0.052                          | 2.906                       | 1.913           | 0.201          | 106.2                                  | 1437.8                           |

R: Replication; G: Genotype; E: Error; Note: \*: Significant at ( $p=0.05$ ) level; \*\*: significant at ( $p=0.01$ ) level

Table 2: Summary of genetic parameters for quantitative traits of garden pea

| Genetic parameters              | Days to 50% flowering | Plant height (cm) | No. of branches plant <sup>-1</sup> | First fruiting node | No. of pods plant <sup>-1</sup> | No. of seeds pod <sup>-1</sup> | Days to marketable maturity | Harvesting span | Dry matter (%) | Protein content (kg ha <sup>-1</sup> ) | Pod yield (kg ha <sup>-1</sup> ) |
|---------------------------------|-----------------------|-------------------|-------------------------------------|---------------------|---------------------------------|--------------------------------|-----------------------------|-----------------|----------------|----------------------------------------|----------------------------------|
| GCV                             | 21.98                 | 21.78             | 9.07                                | 16.58               | 18.20                           | 15.05                          | 13.69                       | 23.71           | 20.09          | 10.68                                  | 5403                             |
| PCV                             | 22.26                 | 21.94             | 10.20                               | 17.17               | 18.70                           | 15.54                          | 13.88                       | 24.03           | 20.23          | 11.35                                  | 5457                             |
| h <sup>2</sup> (Broad Sense)    | 0.98                  | 0.99              | 0.79                                | 0.93                | 0.95                            | 0.94                           | 0.97                        | 0.97            | 0.99           | 0.89                                   | 098                              |
| Genetic advance                 | 25.83                 | 29.72             | 2.61                                | 3.07                | 3.68                            | 1.77                           | 20.91                       | 17.23           | 7.82           | 5.57                                   | 5483                             |
| Gen. Adv. as percentage of mean | 44.73                 | 44.55             | 16.63                               | 32.98               | 36.50                           | 30.03                          | 27.82                       | 48.21           | 41.10          | 20.72                                  | 11021                            |
| General mean                    | 57.74                 | 66.72             | 15.67                               | 9.31                | 10.07                           | 5.91                           | 75.17                       | 35.75           | 19.03          | 26.91                                  | 4975                             |
| Range                           | 34–75                 | 57.50–173.20      | 13.30–18.80                         | 6.13–13.00          | 8.10–14.53                      | 3.47–7.43                      | 55–95                       | 18.00–40.67     | 13.58–30.59    | 23.22–32.67                            | 2149–15047                       |

GCV: Genotypic coefficient of variance; PCV: Phenotypic coefficient of variance



### 3.2.1. Days to 50% flowering

Among 24 genotypes, days to 50% flowering showed a wide range of variation (34–75 days) with grand mean of 57.74 days. High genotypic and phenotypic coefficients of variance were recorded as 21.98 and 22.26%, respectively. High heritability for this character was recorded as 98%. High expected genetic advance and genetic advance as per cent of mean were recorded as 25.83 and 44.73, respectively. Devi et al. (2018) earlier reported high PCV and GCV values for this character. Pal and Singh (2013) had already reported high genotypic and phenotypic coefficient of variation along with high heritability and high genetic advance for Days to 50% flowering. The results are contradictory to the findings of Singh et al. (2019).

### 3.2.2. Plant height

Among 24 genotypes, plant height ranged from 40.12 cm to 85.34 cm with grand mean of 66.72 cm. Karayel and Bozoglu (2015) recorded greater variation for plant height (57.5–173.2 cm). The genotypic and phenotypic coefficients of variance (21.78 and 21.94%) were recorded high for this character, respectively. Similarly, Jagadeesh et al. (2023) reported high PCV and GCV values for plant height. The findings are in agreement with Singh et al. (2019). In present investigation, plant height was noted highly heritable character recording 99% heritability (in broad sense) along with high genetic advance and genetic advance as per cent of mean (29.72 and 44.55), respectively. Estimates of high GCV along with high heritability and genetic advance indicates the presence of additive gene effects suggesting more scope of selection for this trait. Similar findings were reported by Jeberson et al. (2016).

### 3.2.3. No. of branches plant<sup>-1</sup>

Among 24 genotypes, number of branches plant<sup>-1</sup> ranged from 13.30–18.80 with grand mean of 15.67. Present findings are in agreement with Karayel and Bozoglu (2015) showing similar range of variation for number of branches plant<sup>-1</sup>. The genotypic and phenotypic coefficients of variance were recorded low as 9.07 and 10.20%, respectively. These findings could be supported by Mahapatra et al. (2020) reported high variations in branches number plant<sup>-1</sup> at genotypic and phenotypic levels. High heritability (79%) was accompanied with moderate genetic advance as per cent of mean (16.63). Reports are available as low heritability and genetic advance (Sharma and Sharma, 2013) to high heritability coupled with high genetic advance over percent mean (Singh, 2010).

### 3.2.4. First fruiting node

Among 24 genotypes, first fruiting node showed a wide range of variation (6.13–13.00) with grand mean of 9.31. The genotypic and phenotypic coefficients of variance were

recorded moderate as 16.58 and 17.17%, respectively. The heritability was recorded high as 93% for this character. The expected genetic advance (3.07) and genetic advance as per cent of mean (32.98) were recorded as low and high, respectively. Kumari et al. (2008), Kumar et al. (2015) and Singh et al. (2019) reported that high heritability was accompanied with high genetic gain in genetic control of bearing node in pea plants.

### 3.2.5. No. of pods plant<sup>-1</sup>

Among 24 genotypes, number of pods plant<sup>-1</sup> showed a wide range of variation (8.10–14.53) with grand mean of 10.07. Karayel and Bozoglu (2015) and Singh et al. (2019) reported a greater range of variation for pod number plant<sup>-1</sup>. The genotypic and phenotypic coefficients of variance were recorded moderate as 18.20 and 18.70%, respectively. However, Meena et al. (2022) reported high percentage of phenotypic and genotypic variation in this character. The heritability was recorded high as 95% for this character. The expected genetic advance (3.68) and genetic advance as per cent of mean (36.50) were recorded as low and high, respectively. Present findings are supported by Al-Aysh et al. (2015), Meena et al. (2022), and Kavyashree et al. (2023) also reported high heritability and high genetic advance for this character.

### 3.2.6. No. of seeds pod<sup>-1</sup>

Among 24 genotypes, number of seeds pod<sup>-1</sup> significantly ranged from 3.47 to 7.43 with grand mean of 5.91. Karayel and Bozoglu (2015) and Aman et al. (2021) observed almost similar range of seed number pod<sup>-1</sup> (4.0–7.6 and 4.0–9.3, respectively). The genotypic and phenotypic coefficients of variance were recorded moderate as 15.05 and 15.54%, respectively. The heritability was recorded high as 94% for this character. The expected genetic advance (1.77) and genetic advance as per cent of mean (30.33) were recorded as low and high, respectively. Singh et al. (2012) and Kumar et al. (2013) reported that inheritance of seed pod<sup>-1</sup> is the consequent of high heritability and high expected genetic gain as found in our results. This indicates that the character is under the influence of additive gene action and selection of this trait would be effective for genotypic and phenotypic improvement.

### 3.2.7. Days to marketable maturity

Among 24 genotypes, wide range was recorded for days to marketable maturity from 55.00 days to 95.00 days with grand mean of 75.17 days. Similarly, Aman et al. (2021) reported wide range of variability for days to first picking. The genotypic and phenotypic coefficients of variance were recorded moderate as 13.69 and 13.88%, respectively. High heritability was recorded as 97.00% for this character. The expected genetic advance (20.91) and genetic advance as





per cent of mean (27.82) were recorded as moderate and high, respectively. Sharma et al. (2017) earlier reported high heritability coupled with high genetic advance for maturity of pea.

### 3.2.8. Harvesting span

Among 24 genotypes, harvesting span ranged from 18.00 days to 40.67 days with grand mean of 35.75 days. The genotypic and phenotypic coefficients of variance were recorded as high as 23.71 and 24.03%, respectively. The heritability was recorded high as 97% for this character. The expected genetic advance (17.23) and genetic advance as per cent of mean (48.21) were recorded as moderate and high, respectively. The consequences of heritability coupled with high genetic advance showed for this character may be improved through selection method.

### 3.2.9. Dry matter

Among 24 genotypes tested, dry matter showed a wide range of variation (13.58–30.57%) with overall mean of 19.03%. The genotypic and phenotypic coefficients of variance were recorded as high as 20.09 and 20.23%, respectively which indicates the existence of broad genetic base. The heritability for this character was recorded high as 99%. The expected genetic advance (7.82) and genetic advance as per cent of mean (41.10) were recorded as low and high, respectively. Significant variation in dry matter yield and high estimates of heritability along with high expected genetic gain (Rathi and Dhaka, 2007) are in agreement with our findings.

### 3.2.10. Protein content

Among 24 genotypes, protein content varied from 23.22–32.67% with grand mean of 26.91% with grand mean of 26.91%. Significance of our results is supported by Harmankaya et al. (2010) and Karayel and Bozoglu (2015) had earlier reported appreciable range of crude protein in pea. The genotypic and phenotypic coefficients of variance were recorded moderate as 10.68 and 11.35%, respectively. High heritability was recorded for this character (89%). The expected genetic advance (5.57) and genetic advance as per cent of mean (20.72) were recorded as low and high, respectively. Meena et al. (2022) earlier reported high heritability coupled with high genetic advance as percent mean for protein content of pea.

### 3.2.11. Pod yield

Among 24 genotypes, pod yield showed a wide range of variation (2149–15047 kg ha<sup>-1</sup>) with grand mean of 4975 kg ha<sup>-1</sup>. The genotypic and phenotypic coefficients of variance were recorded high as 54.03 and 54.57%, respectively. The heritability for this character was recorded high as 98%. The expected genetic advance and genetic advance as per cent of mean were recorded high as 54.83 and 110.21, respectively. In accordance of our results, similarly high range of variation

for green pod yield in pea was chronically reported by Al-Aysh et al. (2015), Singh et al. (2019) and Aman et al. (2021) along with high estimates of heritability and genetic gain, suggesting that these characters are genetically controlled by additive (heritable) gene action and can be utilized for pea improvement through selection.

### 3.3. Correlation coefficients

The correlation coefficients among eleven characters of garden pea were worked out in all possible combinations at phenotypic and genotypic levels and are presented in Table 3. The present findings revealed that the magnitude of phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the traits as also reported by Rahman et al. (2021) which revealed inherent association among traits. The highest positive correlation was between days to 50% flowering and days to marketable maturity, the highest negative correlation was between harvesting span and dry matter content. The pod yield has significantly positive association with days to 50% flowering, number of pods plant<sup>-1</sup> and number of seeds pod<sup>-1</sup>. However, pod yield was negatively associated with number of branches plant<sup>-1</sup> and harvesting span. Apart from yield, protein content (%) has shown significantly positive association with number of seeds pod<sup>-1</sup> and dry matter (%). Nevertheless, it had negatively strong correlation with harvesting span (days). Documentary reports are available showing strong positive inter-relationship of pod yield with days to flowering (Devi et al., 2018), number of pods plant<sup>-1</sup> and number of seeds pod<sup>-1</sup> as reported by Rahman et al. (2021). No researcher has reported negative association of yield with number of branches plant<sup>-1</sup> and harvesting span. On the other hand, pleiotropy and/or linkage may also be genetic reason for this type of negative association. The pleiotropic genes that affect both characters in the desired direction will be strongly acted upon by selecting and rapidly brought towards fixation.

### 3.4. Path coefficients

In case of correlation, only liner association of characters can be studied that sometimes cause cancellation of important yield component traits during selection. However, path analysis gives the partitions within the correlation coefficients into direct and indirect effects of independent characters on dependent character i.e. yield. Correlation, aided by path coefficient, is a powerful tool to study the character association. The genotypic correlations were partitioned into direct and indirect effects through path coefficient analysis to know the relative importance of 11 characters. The results obtained are presented in Table 4 and Figure 1.

Path coefficient analysis revealed that direct positive effect



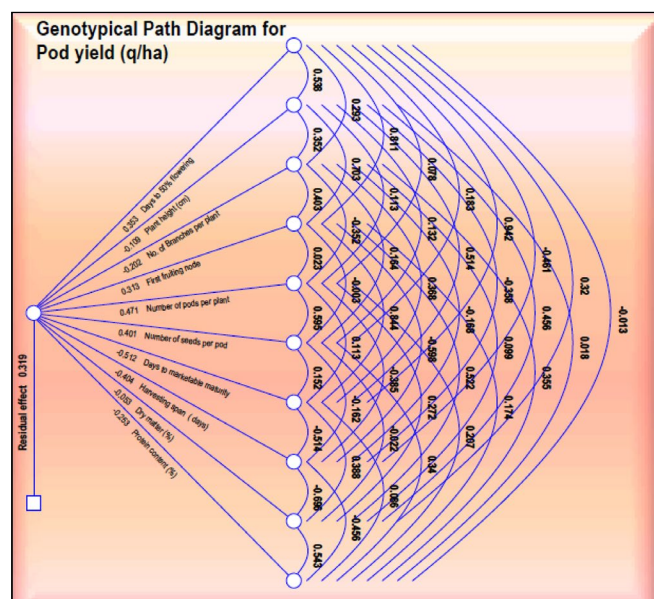


Figure 1: Directs and indirect path of variable characters towards pod yield of garden pea

on pod yield was exhibited by days to 50% flowering, first fruiting node, number of pods plant<sup>-1</sup> and number of seeds pod<sup>-1</sup> and these traits shall be considered as principal component of yield for direct selection of genotypes for the successful breeding programme. Direct selection of number of pods plant<sup>-1</sup> and number of seeds pod<sup>-1</sup> was suggested by Yadav et al. (2010) and Kavyashree et al. (2023), days to 50% flowering, and number of pods plant<sup>-1</sup> by Rahman et al. (2021).

However, the characters viz., Plant height, Number of branches plant<sup>-1</sup>, Days to marketable maturity, harvesting span, Dry matter and Protein content imposing negative direct effects on pod yield can be selected via other characters. The indirect effects of such characters suggested that simultaneous selection of days to marketable maturity and harvesting span would be effective in further breeding programme for improvement of garden pea. Devi et al. (2018) noticed that yield can be substantially improved through indirect contribution of many yield components. However, dry matter and protein content did not

Table 3: Phenotypic and genotypic correlation coefficients for pod yield and quantitative traits in garden peas

| Sl. No. | Character                           |   | Days to 50% flowering | Plant height (cm) | No. of branches plant <sup>-1</sup> | First fruiting node | No. of pods plant <sup>-1</sup> | No. of seeds pod <sup>-1</sup> |
|---------|-------------------------------------|---|-----------------------|-------------------|-------------------------------------|---------------------|---------------------------------|--------------------------------|
| 1.      | Days to 50% flowering               | G | 1.000                 | 0.538             | 0.293                               | 0.811               | 0.078                           | 0.183                          |
|         |                                     | P | 1.000                 | 0.527**           | 0.260*                              | 0.772**             | 0.065                           | 0.179                          |
| 2.      | Plant height (cm)                   | G | 0.538                 | 1.000             | 0.352                               | 0.703               | 0.113                           | 0.132                          |
|         |                                     | P | 0.527**               | 1.000             | 0.311**                             | 0.678**             | 0.108                           | 0.119                          |
| 3.      | No. of branches plant <sup>-1</sup> | G | 0.293                 | 0.352             | 1.000                               | 0.403               | -0.352                          | 0.164                          |
|         |                                     | P | 0.260*                | 0.311**           | 1.000                               | 0.330**             | -0.319**                        | 0.114                          |
| 4.      | First fruiting node                 | G | 0.811                 | 0.703             | 0.403                               | 1.000               | 0.023                           | -0.003                         |
|         |                                     | P | 0.772**               | 0.678**           | 0.330**                             | 1.000               | 0.023                           | -0.003                         |
| 5.      | No. of pods plant <sup>-1</sup>     | G | 0.078                 | 0.113             | -0.352                              | 0.023               | 1.000                           | 0.595                          |
|         |                                     | P | 0.065                 | 0.108             | -0.319**                            | 0.023               | 1.000                           | 0.555**                        |
| 6.      | No. of seeds pod <sup>-1</sup>      | G | 0.183                 | 0.132             | 0.164                               | -0.003              | 0.595                           | 1.000                          |
|         |                                     | P | 0.179                 | 0.119             | 0.114                               | -0.003              | 0.555**                         | 1.000                          |
| 7.      | Days to marketable maturity         | G | 0.942                 | 0.514             | 0.368                               | 0.844               | 0.113                           | 0.152                          |
|         |                                     | P | 0.918**               | 0.508**           | 0.322**                             | 0.806**             | 0.114                           | 0.141                          |
| 8.      | Harvesting span (days)              | G | -0.461                | -0.358            | -0.168                              | -0.598              | -0.385                          | -0.162                         |
|         |                                     | P | -0.451**              | -0.349**          | -0.142                              | -0.566**            | -0.368**                        | -0.150                         |
| 9.      | Dry matter (%)                      | G | 0.320                 | 0.456             | 0.099                               | 0.522               | 0.272                           | -0.022                         |
|         |                                     | P | 0.312**               | 0.451**           | 0.087                               | 0.502**             | 0.263*                          | -0.012                         |
| 10.     | Protein content (%)                 | G | -0.013                | 0.018             | 0.355                               | 0.174               | 0.207                           | 0.340                          |
|         |                                     | P | -0.013                | 0.018             | 0.297                               | 0.153               | 0.203                           | 0.283*                         |
| 11.     | Pod yield (kg ha <sup>-1</sup> )    | G | 28.9                  | 18.9              | -32.7                               | 18.8                | 83.3                            | 60                             |
|         |                                     | P | 27.2*                 | 18.6              | -29.6                               | 18.2                | 81.1**                          | 56.9**                         |

Table 3: Continue...



| Sl. No. | Character                           |   | Days to marketable maturity | Harvesting span | Dry matter (%) | Protein content (kg ha <sup>-1</sup> ) | Pod yield (kg ha <sup>-1</sup> ) |
|---------|-------------------------------------|---|-----------------------------|-----------------|----------------|----------------------------------------|----------------------------------|
| 1.      | Days to 50% flowering               | G | 0.942                       | -0.461          | 0.320          | -0.013                                 | 28.9                             |
|         |                                     | P | 0.918**                     | -0.451**        | 0.312**        | -0.013                                 | 27.2*                            |
| 2.      | Plant height (cm)                   | G | 0.514                       | -0.358          | 0.456          | 0.018                                  | 18.9                             |
|         |                                     | P | 0.508**                     | -0.349**        | 0.451**        | 0.018                                  | 18.6                             |
| 3.      | No. of Branches plant <sup>-1</sup> | G | 0.368                       | -0.168          | 0.099          | 0.355                                  | -32.7                            |
|         |                                     | P | 0.322**                     | -0.142          | 0.087          | 0.297*                                 | -29.6*                           |
| 4.      | First fruiting node                 | G | 0.844                       | -0.598          | 0.522          | 0.174                                  | 18.8                             |
|         |                                     | P | 0.806**                     | -0.566**        | 0.502**        | 0.153                                  | 18.2                             |
| 5.      | No. of pods plant <sup>-1</sup>     | G | 0.113                       | -0.385          | 0.272          | 0.207                                  | 83.3                             |
|         |                                     | P | 0.114                       | -0.368**        | 0.263*         | 0.203                                  | 81.1**                           |
| 6.      | No. of seeds pod <sup>-1</sup>      | G | 0.152                       | -0.162          | -0.022         | 0.340                                  | 60                               |
|         |                                     | P | 0.141                       | -0.150          | -0.012         | 0.283*                                 | 56.9**                           |
| 7.      | Days to marketable maturity         | G | 1.000                       | -0.514          | 0.388          | 0.086                                  | 23.4                             |
|         |                                     | P | 1.000                       | -0.504**        | 0.380**        | 0.071                                  | 23                               |
| 8.      | Harvesting span (days)              | G | -0.514                      | 1.000           | -0.696         | -0.456                                 | -51.2                            |
|         |                                     | P | -0.504**                    | 1.000           | -0.685**       | -0.423**                               | -49.8**                          |
| 9.      | Dry matter (%)                      | G | 0.388                       | -0.696          | 1.000          | 0.543                                  | 21.8                             |
|         |                                     | P | 0.380**                     | -0.685**        | 1.000          | 0.509**                                | 21.3                             |
| 10.     | Protein content (%)                 | G | 0.086                       | -0.456          | 0.543          | 1.000                                  | 6.9                              |
|         |                                     | P | 0.071                       | -0.423**        | 0.509**        | 1.000                                  | 6                                |
| 11.     | Pod yield (kg ha <sup>-1</sup> )    | G | 23.4                        | -51.2           | 21.8           | 6.9                                    | 100                              |
|         |                                     | P | 23                          | -49.8**         | 21.3           | 6                                      | 100                              |

Table 4: The breakup of genotypic correlation into direct (bold) and indirect components in garden pea

| Sl. No. | Character                           | Days to 50% flowering | Plant height (cm) | No. of branches plant <sup>-1</sup> | First fruiting node | No. of pods plant <sup>-1</sup> | No. of seeds pod <sup>-1</sup> | Days to marketable maturity | Harvesting span | Dry matter (%) | Protein content (kg ha <sup>-1</sup> ) |
|---------|-------------------------------------|-----------------------|-------------------|-------------------------------------|---------------------|---------------------------------|--------------------------------|-----------------------------|-----------------|----------------|----------------------------------------|
| 1.      | Days to 50% flowering               | 0.353                 | 0.190             | 0.103                               | 0.287               | 0.027                           | 0.065                          | 0.333                       | -0.163          | 0.113          | -0.004                                 |
| 2.      | Plant height (cm)                   | -0.059                | -0.109            | -0.038                              | -0.077              | -0.012                          | -0.014                         | -0.056                      | 0.039           | -0.050         | -0.002                                 |
| 3.      | No. of Branches plant <sup>-1</sup> | -0.059                | -0.071            | -0.202                              | -0.081              | 0.071                           | -0.033                         | -0.074                      | 0.034           | -0.020         | -0.072                                 |
| 4.      | First fruiting node                 | 0.254                 | 0.220             | 0.126                               | 0.313               | 0.007                           | -0.001                         | 0.264                       | -0.187          | 0.164          | 0.054                                  |
| 5.      | No. of pods plant <sup>-1</sup>     | 0.037                 | 0.053             | -0.166                              | 0.011               | 0.471                           | 0.280                          | 0.053                       | -0.181          | 0.128          | 0.098                                  |
| 6.      | No. of seeds pod <sup>-1</sup>      | 0.073                 | 0.053             | 0.066                               | -0.001              | 0.238                           | 0.401                          | 0.061                       | -0.065          | -0.009         | 0.136                                  |
| 7.      | Days to marketable maturity         | -0.483                | -0.263            | -0.189                              | -0.433              | -0.058                          | -0.078                         | -0.512                      | 0.263           | -0.199         | -0.044                                 |
| 8.      | Harvesting span (days)              | 0.186                 | 0.145             | 0.068                               | 0.242               | 0.156                           | 0.065                          | 0.208                       | -0.404          | 0.281          | 0.184                                  |
| 9.      | Dry matter (%)                      | -0.017                | -0.024            | -0.005                              | -0.028              | -0.015                          | 0.001                          | -0.021                      | 0.037           | -0.053         | -0.029                                 |

Table 4: Continue...



| Sl. No. | Character                        | Days to 50% flowering | Plant height (cm) | No. of branches plant <sup>-1</sup> | First fruiting node | No. of pods plant <sup>-1</sup> | No. of seeds pod <sup>-1</sup> | Days to marketable maturity | Harvesting span | Dry matter (%) | Protein content (kg ha <sup>-1</sup> ) |
|---------|----------------------------------|-----------------------|-------------------|-------------------------------------|---------------------|---------------------------------|--------------------------------|-----------------------------|-----------------|----------------|----------------------------------------|
| 10.     | Protein content (%)              | 0.003                 | -0.005            | -0.090                              | -0.044              | -0.052                          | -0.086                         | -0.022                      | 0.115           | -0.138         | -0.253                                 |
| 11.     | Pod yield (kg ha <sup>-1</sup> ) | 28.9                  | 18.9              | -32.7                               | 18.8                | 83.3                            | 60                             | 23.4                        | -51.2           | 21.8           | 6.9                                    |
|         | Partial R <sup>2</sup>           | 0.102                 | -0.021            | 0.066                               | 0.059               | 0.393                           | 0.241                          | -0.120                      | 0.207           | -0.012         | -0.017                                 |

significantly correlate with pod yield. This is in confirmatory with low to moderate values of direct and indirect effects of both characters towards pod yield. Therefore, individual selection should be the criteria for improvement of dry matter and protein while identifying high yield genotypes. Low magnitude of residual effect (0.319) indicated that the eleven characters included in genetic analysis contributed about 68% of the variability in pod yield of this population. Therefore, these traits could be considered while exercising selection for improvement of pod yield in garden pea.

#### 4. CONCLUSION

High PCV and GCV accompanied with high heritability genetic advance of mean for the characters like days to 50% flowering, plant height, harvesting span, dry matter and pod yield indicated the predominance of additive gene actions. Pod yield showed positive significant association with days to 50% flowering, number of pods plant<sup>-1</sup> and number of seeds pod<sup>-1</sup>. Path analysis revealed that these traits shall be considered as principal component of yield for direct selection of genotypes for the successful breeding programme.

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