Study of correlation and path analysis for yield and yield attributing traits in mungbean [Vigna radiata (L.) Wilczek]

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DOI: https://doi.org/10.22271/chemi.2020.v8.i1af.8586

Abstract
The present study on association of various plant, pod and seed characters with seed yield was carried out using 112 diverse genotypes of mungbean, along with five high yielding checks. The field experiment was laid out in Augmented Block Design at N. E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, India. Observations were recorded on fifteen morphological characters of plant, pod and seed. The genotype differed significantly for all the characters studied. Correlation analysis indicated that seed yield showed positive significant correlation with number of pod per plant, pod diameter, pod length, 100-seed weight, number of cluster, number of leaves, seed diameter, plant height, seed length, pod wall thickness, number of branches and seed density. Path analysis revealed that number of pod per plant and 100-seed weight exerted a high magnitude of positive direct effect, pod length showed moderate effect while number of cluster and seed density exerted positive but low magnitude of direct effect on seed yield. Selection strategy based on these characters having high direct effect coupled with positive correlation with seed yield will be rewarding in mungbean improvement programme.

Keywords: Correlation, mungbean, path analysis, seed yield, Vigna radiata

Introduction
Mungbean [Vigna radiata (L.) Wilczek] is priced among pulse crops as its seeds are high in essential dietary protein. In India, it is third most important legume crop and is one of the important grain legumes of global economic importance. Mungbean also known as green gram are cultivated in different agro-climatic conditions and soil types in India and various other countries like China, Thailand, Philippines, Indonesia, Burma, and Bangladesh and in hot and dry regions of South Europe and Southern USA (Singh et al., 2005) [15]. Mungbean grain contains 51% carbohydrates, 26% protein, 10% moisture, 4% mineral and 3% vitamins. Mungbean grains are rich in iron (6 mg per 100g of dry seed). The amino acid profile of mungbean (in g/16g N) comprises lysine (7), cysteine (0.6), methionine (1), threonine (3.5) and tryptophan (0.4) and is complementary to that of cereal grains (Asaduzzaman et al., 2008) [3]. Correlation coefficient analysis measures the mutual relationship between plant characters and determines the component characters on which selection can be based for improvement in yield. If the association between two characters is considerably positive, it will increase the rate of genetic advancement, while the negative correlation will decrease the genetic improvement progress after selection for the character. Path coefficient analysis gives an idea about the contribution of each independent character to the dependent character, i.e. seed yield, in this study. Since the mutual relationship of component characters might vary both in the magnitude and direction, it may tend to vitiate the association of dependent character with the component characters. It is, therefore, necessary to partition the correlation coefficients of the component characters into their direct and indirect effects on the dependent character. In the present investigation, association of various plant, pod and seed characters with economic yield was determined by studying the correlation and direct/indirect effects of these characters on seed yield.
Materials and Methods
The study of correlation and path analysis in mungbean for yield and yield attributing traits was carried out at G.B. Pant University of Agriculture and Technology, Pantnagar, India, during Kharif 2010-2011. Geographically Pantnagar is situated at 29.0°N latitude and 79.30°E longitude and at an altitude of 243.84 m above the mean sea level. This falls in the humid subtropical zone and situated in the Tarai belt in the foothills of Shivalik range of the great Himalayas. The field experiment was laid out at N. E. Borlaug Crop Research Center in Augmented Block Design (Federer, 1961) [8], which consisted 4 blocks with 5 checks repeated in each block. Two rows of each entry were planted with keeping row length 4 meter, row to row distance 30 cm and plant to plant distance maintained at 10 cm. The experimental material consisted of 112 diverse germplasm lines of mungbean along with five high yielding checks (Table 1).

Observations were recorded from five randomly selected plant for fifteen morphological characters viz. days to 50 percent flowering, plant height (cm), number of leaves, number of branches, number of clusters, number of pods per cluster, number of pods per plant, pod length (cm), pod diameter (mm), pod wall thickness (mm), seed length (mm), seed diameter (mm), 100-seed weight (gm), seed density (gm/ml) and seed yield (kg/ha). The mean values from five randomly selected plants were calculated and used for the statistical analysis.

The estimation of correlation coefficient was done using formula given by Searle (1961) [13] and test of significance was carried out by method described by Snedecor and Cochran (1967) [16]. The correlation coefficient were further partitioned into direct and indirect effect with the help of path coefficient analysis as suggested by Wright (1921) [18] and elaborated by Dewey and Lu (1959) [5]. Seed yield was considered as dependent variable as factors assumed to be influenced by the other characters called independent variables as causes.

Table 1: Details of mungbean germplasm

| S. N. | Germplasm | S. N. | Germplasm | S. N. | Germplasm | S. N. | Germplasm |
|-------|-----------|-------|-----------|-------|-----------|-------|-----------|
| 1.    | PM-2      | 31.   | PM 06-48  | 61.   | MH-318    | 89.   | Pusa-672  |
| 2.    | PM-3      | 32.   | PM 06-49  | 62.   | Mauritius | 90.   | IPM 02-19 |
| 3.    | PM-4      | 33.   | PM 06-51  | 63.   | Mung-1    | 91.   | IPM 02-17 |
| 4.    | PM-5      | 34.   | PM 06-57  | 64.   | V. radiata var sublobata | 92.   | MH-521    |
| 5.    | PM-6      | 35.   | MH-429    | 65.   | Pant Mung-5 | 94.   | TM 96-2   |
| 6.    | PM 03-2   | 36.   | NH-54     | 66.   | Harsha    | 95.   | COGG-912  |
| 7.    | PM 03-4   | 37.   | NM-94     | 67.   | OBGG-52   | 97.   | Pusa-871  |
| 8.    | PM 03-5   | 38.   | NM-1(Mutant) | 68.   | 12/333    | 98.   | PM 06-32  |
| 9.    | PM 03-7   | 39.   | ICM-1     | 69.   | SML-668   | 99.   | PM 06-33  |
| 10.   | PM 03-9   | 40.   | VC 6790 A | 70.   | 45-8-1    | 100.  | PM 06-34  |
| 11.   | PM 03-11  | 41.   | VC 6769(57-99) | 71.   | AKM-9904  | 101.  | PM 06-35  |
| 12.   | PM 03-12  | 42.   | VC 7960-88| 72.   | Pre Dred  | 102.  | PM 06-36  |
| 13.   | PM 03-13  | 43.   | BDYR-1    | 73.   | Samrat    | 103.  | PM 06-37  |
| 14.   | PM 03-14  | 44.   | BDYR-2    | 74.   | NDM 5-3   | 104.  | PM 06-39  |
| 15.   | PM 03-15  | 45.   | Barimung-4| 75.   | MH-429    | 105.  | PM 06-43  |
| 16.   | PM 03-16  | 46.   | Barimung-5| 76.   | NIABM     | 106.  | PM 06-46  |
| 17.   | PM 03-17  | 47.   | Barimung-7| 77.   | VC 1997 A | 107.  | KM 09-174 |
| 18.   | PM 03-18  | 48.   | Barisan Local | 78.   | VC 6040 A | 108.  | KM 09-192 |
| 19.   | PM 03-19  | 49.   | Mauritius Local | 79.   | VC-7960   | 109.  | SM 10-505 |
| 20.   | PM 03-20  | 50.   | Pusa Vishal| 80.   | HUM-16    | 110.  | SM 10-503 |
| 21.   | PM 03-21  | 51.   | UPM 02-16 | 81.   | NDM-1     | 111.  | SM 10-533 |
| 22.   | PM 03-22  | 52.   | UPM 98-1  | 82.   | NDM 5-31  | 112.  | SM 10-529 |
| 23.   | PM 03-23  | 53.   | UPM 98    | 83.   | MH-418    | 113.  | V. trilobata X |
| 24.   | PM 03-24  | 54.   | UPM 03-18 | 84.   | ML-133    | 114.  | V. sublobata X |
| 25.   | PM 05-4   | 55.   | UPM 98-10 | 85.   | CN 9-5    | 115.  | V. silvestris X |
| 26.   | PM 06-6   | 56.   | UPM 93-3  | 86.   | Mung Local | 116.  | IPM 02-19 |
| 27.   | PM 06-31  | 57.   | PUM 99-3  | 87.   | Pusa Ratna | 117.  | PM 06-50  |
| 28.   | PM 06-41  | 58.   | PM 08-16  | 88.   | Pusa-9531 |

Results and Discussion
Crop improvement programmes depends to a large extent on availability of sufficient variability and association among different characters which are the pre-requisite for executing an effective selection programme. Seed yield, being a complex quantitative trait, is dependent on a number of component characters. Therefore, knowledge of association of different components together with their relative contributions has immense value in selection.

Correlation
The estimation of correlation coefficients among different characters has been presented in Table 2. The seed yield showed highly significant and positive correlation with number of pod per plant (0.55), followed by pod diameter (0.54), pod length (0.54), 100-seed weight (0.52), number of cluster (0.47), number of leaves (0.42), seed diameter (0.42), plant height (0.38), seed length (0.36), pod wall thickness (0.34), number of branches (0.31) and seed density (0.30). Number of pod per cluster was significant and positively correlated with seed yield (0.31). Higher number of pods per plant with longer pod and seed size and diameter directly contributed towards the seed yield. Moreover, high correlation of 100-seed weight and plant height with seed yield also obtained in mungbean by Anwari and Sochandi (1999) [22]; Makeen et al. (2007) [9]; Tabassum et al. (2010) [17];
Reddy et al. (2011) [11], Kumar et al. (2013) [10] and Hemavathy et al. (2015) [8]. The days to 50% flowering had non-significant negative correlation (-0.11) with seed yield, similar negative correlation also reported by Rohman et al. (2003) [12] and Garg et al. (2017) [13] in mungbean.

Path analysis
The correlation coefficient becomes more meaningful when correlation coefficient are partitioned into components of direct and indirect effects through path analysis, because correlation coefficients indicate only the inter relationship of the characters irrespective of cause and effect (Dewey and Lu, 1959) [9]. For path analysis, seed yield was taken as the dependent variable and all other 14 characters used for correlation studies were taken as causal variables. The results are presented in table 3. Path analysis revealed that number of pod per plant (0.60) and 100-seed weight (0.47) exerted a high magnitude of positive direct effect on seed yield. These results were corroborating with the findings of Rohman et al. (2003) [12] and Makeen et al. (2007) [9]. Moderate direct effect showed by pod length (0.27) while number of cluster (0.14) and seed density (0.13) exerted low magnitude of direct effect. The moderate direct effect of pod length also had been observed study carried out among 54 genotype of mungbean by Alom et al. (2014) [1]. The direct effect on seed yield was observed negligible for rest of the characters.

Table 2: Correlations between different characters of Mungbean.

| Character        | Days to 50% flowering | Plant height | No. of leaves | No. of branches | No. of cluster | No. of pods/cluster | No. of pods/plant | Pod length | Pod diameter | Pod wall thickness | Seed length | Seed diameter | 100-seed weight | Seed density | Seed yield |
|------------------|-----------------------|--------------|---------------|----------------|---------------|---------------------|-------------------|------------|--------------|-------------------|-------------|---------------|----------------|-------------|-----------|
| Days to 50% flowering | 1.00                  |              |               |                |               |                     |                   |            |              |                   |             |               |                |             |           |
| Plant height     |                       |              |               |                |               |                     |                   |            |              |                   |             |               |                |             |           |
| No. of leaves    | 0.22**                | 0.55**       | 1.00          |                |               |                     |                   |            |              |                   |             |               |                |             |           |
| No. of branches  | 0.09                  | 0.38**       | 0.33**        | 1.00          |               |                     |                   |            |              |                   |             |               |                |             |           |
| No. of pods/cluster | 0.24**               | 0.48**       | 0.65**        | 0.17          | 1.00          |                     |                   |            |              |                   |             |               |                |             |           |
| No. of pods/plant | 0.03                  | 0.39**       | 0.21*         | 0.31**        | -0.001        | 1.00               |                   |            |              |                   |             |               |                |             |           |
| Pod length       | -0.33**               | 0.09         | -0.11         | 0.09          | -0.01         | -0.004             | -0.08             | 1.00       |              |                   |             |               |                |             |           |
| Pod diameter     | -0.29**               | 0.19*        | -0.02         | 0.17          | 0.02          | 0.14               | -0.02             | 0.70**     | 1.00         |                   |             |               |                |             |           |
| Pod wall thickness| 0.01                  | 0.34**       | 0.18*         | 0.03          | 0.15          | 0.09               | 0.03              | 0.37**     | 0.49**       | 1.00               |             |               |                |             |           |
| Seed length      | -0.28                 | -0.004       | -0.16         | 0.02          | -0.15         | -0.12              | -0.19             | 0.65**     | 0.73**       | 0.27**            | 1.00        |               |                |             |           |
| Seed diameter    | -0.23                 | 0.17         | 0.01          | 0.09          | -0.01         | 0.11               | -0.06             | 0.65**     | 0.77**       | 0.39**            | 0.65**      | 1.00          |                |             |           |
| 100-seed weight  | -0.32**               | -0.13        | -0.15         | 0.03          | -0.22*        | -0.04              | -0.27**           | 0.56**     | 0.61**       | 0.24**            | 0.65**      | 0.53**       | 1.00           |             |           |
| Seed density     | -0.07                 | -0.18        | -0.19*        | -0.04         | -0.24*        | -0.11              | -0.26**           | 0.22*      | 0.24*        | 0.21*             | 0.67**      | 1.00          |                |             |           |
| Seed yield       | -0.11                 | 0.38**       | 0.42**        | 0.31*         | 0.47**        | 0.23*              | 0.55**            | 0.54**     | 0.34**       | 0.36**            | 0.42**      | 0.52**       | 0.30**         | 1.00        |           |

* Significant at 5% of level of probability
** Significant at 1% of level of probability

Among the characters studied high positive indirect effect was obtained for number of pods per plant via plant height (0.315), number of leaves (0.428), number of cluster (0.445), number of pod per cluster (0.206), while high negative indirect effect obtained via 100-seed weight (-0.155) and seed density (-0.155). 100-seed weight exerted high positive indirect effect via pod length (0.26), pod diameter (0.284), seed length (0.301), seed diameter (0.248) and seed density (0.310). Such an observation was also reported by Rohman et al. (2003) [12], Biradar et al. (2007) [4] and Tabassum et al. (2010) [17]. The residual effect of path analysis was low (0.137), which shows that few more traits may be included in the study to see the pattern of interaction on seed yield. A greater yield response is obtained when the character for which indirect selection is practiced has a high heritability and a high correlation with yield. Searle (1965) [14] has given the minimum combinations of heritability and correlation coefficient values necessary for indirect selection to be more efficient than direct selection for yield.

Among the characters studied from the path analysis traits viz., number of pod per plant, number of cluster, 100-seed weight and seed density exerted a high magnitude of direct effect on seed yield and also exhibited highly significant and positive correlation with seed yield. Therefore, selection strategy based on these characters for seed yield improvement will be rewarding in mungbean.
Table 3: Path coefficient analysis showing direct and indirect effect of component characters on seed yield of mungbean

| Characters | Correlation with seed yield | Direct effect | Days to 50% flowering | Plant height | No. of leaves | No. of branches | No. of pod clusters | No. of pods/cluster | No. of pods/plant | Pod length | Pod diameter | Pod wall thickness | Seed length | Seed diameter | 100-seed weight | Seed density |
|-----------|-----------------------------|--------------|-----------------------|--------------|---------------|----------------|-------------------|-------------------|-----------------|------------|-------------|-------------------|------------|--------------|----------------|-------------|
| Days to 50% flowering | -0.11 | -0.07 | -0.013 | -0.014 | -0.006 | -0.016 | -0.002 | -0.016 | 0.022 | 0.019 | -0.001 | 0.019 | 0.015 | 0.021 | 0.005 |
| Plant height | 0.38** | 0.04 | 0.007 | 0.021 | 0.014 | 0.018 | 0.015 | 0.020 | 0.003 | 0.007 | 0.013 | -0.0001 | 0.006 | -0.005 | -0.007 |
| No. of leaves | 0.42** | -0.03 | -0.006 | -0.015 | -0.009 | -0.017 | -0.006 | -0.019 | 0.003 | 0.001 | -0.005 | 0.004 | -0.0004 | 0.004 | 0.005 |
| No. of branches | 0.31** | 0.07 | 0.006 | 0.025 | 0.021 | -0.011 | 0.020 | 0.019 | 0.006 | 0.011 | 0.002 | 0.002 | 0.006 | -0.002 | -0.003 |
| No. of pod clusters | 0.47** | 0.14 | 0.033 | 0.066 | 0.091 | 0.023 | -0.0002 | 0.103 | -0.002 | 0.0001 | 0.021 | -0.020 | -0.001 | -0.030 | -0.033 |
| No. of pods/plant | 0.23* | 0.01 | 0.0002 | 0.003 | 0.001 | 0.002 | 0.000 | - | 0.002 | 0.00003 | 0.001 | 0.001 | 0.001 | -0.0002 | 0.001 |
| Pod length | 0.54** | 0.27 | -0.091 | 0.024 | -0.029 | 0.025 | -0.003 | -0.001 | -0.021 | - | 0.193 | 0.102 | 0.177 | 0.177 | 0.153 |
| Pod diameter | 0.54** | 0.07 | -0.020 | 0.013 | -0.001 | 0.012 | 0.001 | 0.010 | -0.001 | 0.049 | - | 0.034 | 0.051 | 0.054 | 0.042 | 0.017 |
| Pod wall thickness | 0.34** | 0.06 | 0.001 | 0.021 | 0.011 | 0.002 | 0.009 | 0.005 | 0.002 | 0.023 | 0.030 | - | 0.017 | 0.024 | 0.016 | 0.007 |
| Seed length | 0.36** | -0.09 | 0.024 | 0.0003 | 0.014 | -0.002 | 0.013 | 0.010 | 0.017 | -0.057 | -0.064 | -0.024 | - | -0.057 | -0.057 | 0.030 |
| Seed diameter | 0.42** | -0.05 | 0.011 | -0.008 | -0.001 | -0.004 | 0.0004 | -0.005 | 0.0031 | -0.031 | -0.037 | -0.019 | -0.031 | - | -0.026 | -0.010 |
| 100-seed weight | 0.52** | 0.47 | -0.147 | -0.062 | 0.070 | 0.016 | -0.100 | -0.017 | 0.120 | 0.260 | 0.264 | 0.119 | 0.301 | 0.248 | - | 0.310 |
| Seed density | 0.30** | 0.13 | -0.009 | -0.023 | -0.025 | -0.006 | -0.031 | -0.014 | -0.034 | 0.029 | 0.031 | 0.016 | 0.044 | 0.028 | 0.087 | - |

Residual factor = 0.137

Acknowledgements

The author is thankful for advisor and department of the Genetics and Plant Breeding, G.B. Pant University of Agriculture and Technology, Pantnagar, India for their valuable guide and facilities for conducting the experiment.

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